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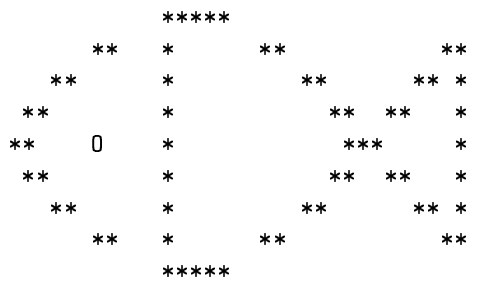
From the Editors

In many countries, the first of April is the day of jokes (in particular in newspapers). So, be careful.



Claudine Kahane and Thierry Forveille

Abstracts of recently accepted papers

Molecular observations of O- and C-rich circumstellar envelopes

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We present observations of 10 microwave transitions of the molecules SiO, HCN, HNC, SiS, HC_3N, CS, SO, and ^{13}CO in a total sample of 47 evolved stars. The studied sources are mainly O- and C-rich standard AGB stars, as well as O-rich red supergiants, S-type stars, protoplanetary nebulae and detached envelopes. We also take into account observations of these transitions, as well as of ^{12}CO 1-0, from the literature. We find that the molecules can be classified as "O-like" (SiO and SO) and "C-like" (HCN, HNC, SiS, HC_3N and CS). The emission of O-like molecules is significantly stronger in O-rich stars than in C-rich sources, and the opposite holds for C-like species. The behaviour of ^{12}CO and ^{13}CO is found to be intermediate between those of O-/C-like species. We have estimated the molecular abundances in most of the studied objects. Our results indicate

that the abundance of the carbon-bearing molecules HCN, HNC and CS in O-rich circumstellar envelopes can only be explained assuming the presence of an active photochemistry in their outer layers. In other cases, such as HCN and CS in C-rich AGB stars, the derived abundances are compatible with LTE chemical models. The SiO and SiS abundances in O-rich and C-rich standard sources can also be explained by LTE chemistry if we assume moreover some depletion onto grains. We finally discuss the chemical properties of some individual interesting sources.

Accepted by Astron. Astrophys. *For preprints, contact* bujarrabal@cay.es

Numerical Calculations of SiO Maser Emission, I : Intensity and Variability

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A model for the excitation and emission of SiO masers in evolved stars, that includes a non-local treatment of the radiative transfer, is presented. The approximations made and their effects, the sources of numerical noise, and in general the reliability of the model are discussed. The code is shown to give an important amount of information on the theoretical expectations for SiO maser emission. The masers are supposed to be placed in an inner quasi-stationary layer of the circumstellar envelope, the properties of which are discussed in view of the available information. The numerical predictions are generally in good agreement with the observational data. In particular, the calculated intensity attains the measured level for a wide range of physical conditions. The maser pump is found to be dominantly radiative, acting through the Δv=1 SiO vibrational transitions. Collisional pump is also possible, but probably gives only a marginal contribution to the total maser output. The radiative maser pump naturally explains the observed dependence of the maser intensity on the stellar far infrared continuum, both from object to object and during the stellar variability cycle. However some observational features, like the well known low intensity of the v=2 J=2-1 line and the possible spatial coincidence of the J=1-0 v=1 and v=2 masers, are not reproduced by the numerical results; possible explanations to this disagreement are discussed. This is the first paper of a series, of which the second part deals with the predicted spatial extent of the SiO maser emission.

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Numerical Calculations of SiO Maser Emission, II : Angular Extent

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This is the second paper of a series devoted to the detailed study of the theoretical properties of SiO masers in evolved stars. In the first paper we present the maser model, discussing the numerical noise and general reliability of the calculations. The physical and chemical conditions probably present in the maser region are also discussed in that article. This second paper deals with the theoretical apparent extent of the masers. The numerical treatment of the maser excitation takes into account the non-local radiative interactions between distant points in the maser cloud, and is therefore particularly well adapted to the study of the brightness spatial distribution of the maser emission. The calculations predict the existence of both very compact spots and wider distributions, emitting comparable total fluxes and possibly coexisting in the same objects. The extended features are probably ring-like and have a radius of a few 10^{14}cm. The compact spots can be smaller than or of the order of 10^{12}cm in diameter, and are expected to be distributed in the above wide structure. The variability during the stellar cycle of both components is expected to be different, the compact emission is predicted to present relatively small variations, though the extended emission should vary somewhat more

strongly than the stellar IR continuum. These numerical results are in general agreement with the observations, but existing data are scarce and some observational work would still be necessary to confirm the theoretical predictions.

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The C/O abundance ratio in the detached circumstellar envelopes around carbon stars

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We present molecular observations of a sample of five 'detached envelopes' surrounding C-rich evolved stars: S Sct, TT Cyg, U Ant, U Cam and R Scl. The observed lines are ^{12}CO J=2-1, HCN J=1-0, HNC J=1-0, SiS J=5-4, HC_3N J=10-9, CN N=1-0, CS J=5-4, SiO J=3-2, SO J_N=6_5-5_4, and ^{13}CO J=2-1 (observations from the literature, including results for the lines ^{12}CO J=1-0, CS J=3-2 and SiO J=2-1, are also taken into account). We confirm the presence of two emitting shells in S Sct and TT Cyg. We also find a two-shell structure in U Cam and argue that the envelope of R Scl detected in molecular emission is also probably detached. The (very probable) detection of HCN emission from the inner envelope of S Sct and its unexpected two-peak structure are remarkable. In the inner shells of S Sct and U Cam and the outer shells of U Cam and R Scl, the chemistry is found to be dominantly C-rich, from the comparison of the line intensity ratios with those usually found in standard evolved stars. We note the lack of detected molecular emission, other than CO lines, from the outer envelopes around S Sct and TT Cyg, for which we cannot conclude about the dominant chemistry. We have then not found any sign of O-rich chemistry in the observed detached shells around C-rich evolved stars.

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Detection of salt water around the Fish Nebula

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We report the first detection of unknown infrared bands in the vicinity of the Fish Nebula. The frequency shift of the observed spectrum is interpreted in terms of pentapole-pentapole interaction between the water molecules and sodium chloride small particules. The relative abundance of sodium chloride is estimated to be 7g/l. A number of narrow features are superposed to the broad bands. They are tentatively assigned to aromatic compounds (peper, garlic and carrots are among the most likely candidates). We have analysed the spectrum in terms of thermal excitation and velocity field. We concluded that the water is thermalized at 363K and shows large scale turbulent motions. This result suggests that strong interactions between the salt water medium and the Fish Nebula are likely to exist and we describe the dedicated instrument (F.O.R.K.) we intend to build to test the effects of these interactions.

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Short time scale monitoring of SiO sources

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We present the results of a short time scale monitoring of SiO maser emission (v=1 J=1-0 transition) in four known strong sources. These sources were monitored nightly for a period of about a month. The aim of these observations is to investigate the possible presence of variations in the maser lines on time scales of a few days to weeks, due to sound waves propagating out from the central star. If sound waves are responsible for the mass loss of certain cool giants, as suggested by Pijpers and Hearn (1989) and Pijpers and Habing (1989), local variations in density and relative velocity are expected just above the stellar photosphere. These could give rise to variations in any narrow spectral line formed in this region, and therefore in particular in the SiO maser lines. Our observations indicate that variations in the line shape (leading to relative changes in the intensity of about 20%) occur in the SiO emission of Mira type stars, within short time scales of 10-20 days. The main component of the profile variability is consistent with a displacement of the velocity centroid of the dominant maser peaks, by about 1 km s^{-1} in the average. Apparent variations in the total line flux were also found, but could be partially due to calibration uncertainties.

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Near infrared speckle interferometry and water maser observations of carbon stars with oxygen-rich circumstellar

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We rule out the binary hypothesis for carbon stars with oxygen-rich shells by two complementary observing methods: Infrared speckle interferometry at 2.3μm and 3.5μm shows that the carbon stars BM Gem, EU And and V778 Cyg cannot have M-type companions of AGB luminosity at separations larger than 0.04". Monitoring of the water maser emission in EU And and V778 Cyg over five years did not show any velocity variations exceeding 0.06 km s^{-1} yr^{-1}, which excludes the possibility that the maser emission is due to an M-type companion in a close orbit around the carbon star. From the other suggestions about the nature of these stars, the circumbinary disc model remains the most plausible. From the constancy of the water maser lines we infer a minimum radius of the disc of 45 sin i AU for a solar mass star.

The properties of the maser emission (variability, shape of the spectrum etc.) are inconspicuous for water masers in semiregular variable stars and give by themselves no indication to the peculiar nature of the parent stars. No water maser emission was detected from IRAS 19139+5412 (NC 83) and 21566+5309 (MQ Cyg), two other carbon stars suspected to have an oxygen-rich environment.

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H_2O observations of J-type carbon stars

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The detection of five new H_2O masers in J-type carbon stars is reported, confirming the suggestion made earlier that they have an oxygen-rich environment. This increases the sample of peculiar carbon stars of this type to 13. The high maser detection rate suggests that perhaps all J-type carbon stars with IRAS flux ratios

$S_{25}/S_{12} > 0.45$ have oxygen-rich environment. Two of the new stars show large radial velocities, stimulating the suggestion that these carbon stars belong to the metal-weak halo population.

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Nebular emission lines in IRAS 10215−5916

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From low and high resolution spectroscopic observations of IRAS 10215−5916 we have discovered the presence of nebular emission lines in this G-type supergiant star in the post-AGB stage. From its high resolution spectrum we derived an expansion velocity of 17 km s^{-1} for the shell, similar to the values usually observed in planetary and proto-planetary nebulae. The images taken in the near infrared show that IRAS 10215−5916 is slightly extended and asymmetric. Although we cannot rule out a possible binary nature for the central star of this IRAS source, in which a hot component could be the responsible for the observed nebular emission, no indications of binarity have been found so far. We suggest that the observed spectrum and morphology could be produced by the asymmetric mass loss of a single star in the post-AGB phase. Post-AGB mass loss can play a fundamental role on shortening the transition time towards the planetary nebula stage and favour the formation of the bipolar structures commonly observed in evolved planetary nebulae. In this sense, it is shown that this mass loss is more intense and frequent for massive progenitors of PNe.

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An extensive study of planetary nebulae in the Galactic bulge: V. Monte-Carlo simulations of an observed sample

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We have analyzed the population of Galactic bulge planetary nebulae (GBPN) by means of Monte-Carlo methods. Statistical tests were used to compare observed histograms with simulated distributions of radio fluxes, angular diameters, surface brightnesses and nebular ionized masses.

We have shown how selection effects operate in observed diagrams and alter our understanding of the GBPN population: for example, the observed central star mass distribution is biased upwards with respect to the intrinsic one.

The present observational constraints allow a large number of solutions, and it is essential to measure the nebular expansion velocities for a better understanding of the GBPN population. Still, all the accepted solutions correspond to a very narrow central star mass distribution, centered on a value not larger than 0.6 $M_{\odot}$.

Incidentally, we have found that, in the synthetic populations which are compatible with the observations, there is a large proportion of density bounded nebulae. This is an important result for studies of the HR diagram for central stars.

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Confrontation of theoretical tracks for post-AGB stars with observations of planetary nebulae

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We have constructed a distance-independent diagram to test published theoretical tracks for the evolution of post-AGB stars by comparing them with the Galactic planetary nebulae data base. We have found no inconsistency between observations and the set of tracks computed by Schonberner (1981, 1983) and Blocker & Schonberner (1990). On the other hand, observations do not seem support the large transition times between the end of the AGB superwind and the beginning of the planetary nebula ionization phase adopted in the models of Vassiliadis & Wood (1993).

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Comparison of the masses of planetary nebula nuclei derived from different methods

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We present some results of an extensive and uniform analysis of the planetary nebula nuclei from samples examined by Mendez et al. and Gathier and Pottasch. The present study uses distance independent diagrams. The theoretical tracks have been modified so that they can be directly compared in the diagrams to the observed central star positions. From this comparison the central star masses have been derived. Our results are in contradiction with those from the above cited studies. Possible explanations of the differences are presented.

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The OH/IR-planetary nebula connection: Space distribution and kinematics

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We investigate the connection between AGB stars, especially OH/IR stars, and planetary nebulae (PN). The latter comprise a mixed population, with a range of spatial and kinematical properties, attributed to the age and mass of the progenitor star. We propose a classification scheme for OH/IR stars based on the separation of the OH peaks and the IRAS [12-25] colour index. It is shown that the OH/IR stars can be separated into classes with spatial and kinematical characteristics resembling those of the corresponding PN types.

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Planetary nebulae and the helium-to-metals enrichment ratio

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A sample of planetary nebulae (PN), galactic and extragalactic HII regions and blue compact galaxies (BCG) was used in order to obtain the helium-to-metals enrichment ratio, dY/dZ. Adopting a simple linear variation for the helium abundance with metals, and taking into account the contamination of the observed helium abundance in PN by the fresh helium produced in their central stars, it is shown that dY/dZ> 3, and that the linear model is limited to low metallicities. Finally, we conclude that the simple model of galactic chemical evolution is unable to explain the observed enrichment ratio unless infall of gaseous material on to the galactic disk is considered.

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High Resolution Optical Imaging of The "Frosty Leo Nebula"

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High resolution optical images have been obtained of IRAS 09371+1212 (the 'Frosty Leo' Nebula). The images were taken with the DAO/CFHT High Resolution Camera using broad-band V and I filters and with a intermediate-band H_α filter. The red filters, particularly H_α, show that the bipolar nebula is surrounded by a nearly spherical envelope of material 30" in diameter. The high resolution images allow a detailed study of changes in the nebular morphology with wavelength. The ansae remain stationary with wavelength, whereas the positions of the lobes and the position angle of the disk change with wavelength from the optical to the near-infrared. These results suggest that the ejection process is colliminated by the disk, which has been precessing with time. The possibility that the Frosty Leo nebula is not a post-AGB star but a pre-main sequence object formed in isolation from interstellar clouds is discussed.

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Planetary Nebulae: A Modern View

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Our current understanding of the origin and evolution of planetary nebulae is reviewed. We now recognize that a planetary nebula represents a dynamical system which evolution is tightly coupled to the evolution of the central star. Not only is the ionization structure of the nebula controlled by the radiative output from the central star, the dynamics and morphology of the nebula are heavily influenced by the mechanical energy output from the central star. Since the time scale of evolution of the central star is strongly dependent on its mass, the extent of the radiative and mechanical interactions between the star and the nebula not only vary with time, but also vary with stellar mass. The physical properties of planetary nebulae are discussed under this context.

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The Molecular Emission-Line Spectrum of IRC+10216 Between 330 and 358 GHz

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We have conducted a spectral line survey of IRC+10216 using the Caltech Submillimeter Observatory to an average sensitivity of $\lesssim 95$ mK. A deconvolution algorithm has been used to derive the continuous single-sideband spectrum from 330.2 to 358.1 GHz. A total of 56 spectral lines were detected of which 54 have been identified with 8 molecules and a total of 18 isotopomers. The observed lines are used to derive column densities and relative abundances for the detected species. Within this frequency range the spectral lines detected contribute the majority of the total flux emitted by IRC+10216. We use the derived column densities and excitation temperatures to simulate the molecular line emission (assuming LTE) at frequencies up to 1000 GHz. The observed and simulated flux from line emission is compared to broadband total flux measurements and to dust emission assuming a power-law variation of the dust emissivity. We conclude that significant corrections for the line flux must be made to broadband flux measurements of IRC+10216 at wavelengths longer than $\sim 750\,\mu$m.

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Polarized emission line profiles in the core and halo of NGC 7027

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High spectral resolution linear polarization line profiles of the planetary nebula NGC 7027 have been obtained in the [O III], Hα and [N II] emission lines. At positions offset 20″ N and S of the bright optical knot, the [O III] line profile is upto 40% linearly polarized with a systematic increase in polarization from negative to positive velocity. Such high polarization can only arise through dust scattering, confirming the presence of a neutral dusty circumstellar halo, for which evidence had been found previously. The magnitude of the polarization and the velocity profile can plausibly be modelled by amorphous carbon dust with an expansion velocity similar to that of the molecular envelope.

Over the bright knot the [O III] line has a linear polarization of 0.2% at the line peak but increasing to 9% in a positive velocity wing, which extends to +70 kms^{-1}. This polarized wing is too extended to be explained by single scattering from moving dust grains, and the position angle of the polarization vector rotates by $\sim 70°$ across this polarization feature. Multiple scattering is probably occuring, perhaps with velocity doubling as light is reflected across the central ionized cavity by dust in the dense waist found in CO maps.

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Radio and infrared emission from a [WC]-type planetary nebula in the LMC

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Radio continuum emission has been detected from a planetary nebula in the Large Magellanic Cloud: this is the first radio continuum detection for any planetary nebula outside our galaxy. The radio flux density is a factor of two lower than predicted from the Hβ flux. This could be due either to a two-component morphology or to a stellar contribution to the Hβ emission. We have modeled the optical and infrared spectrum using the photo-ionisation code Cloudy: a very good fit is obtained if we assume the nebula is carbon rich. The derived diameter implies an evolutionary age of the nebula of < 1000 yr, similar to what is derived from the IRAS colours alone. The central star, which is of [WC] type, has a much higher stellar temperature than Galactic [WC] stars showing similar circumstellar IRAS colours. An explanation could be that the expansion velocity of the nebula is lower than those of its galactic counterparts. This radio detection indicates that accurate nebular luminosities could be determined from their radio emission for many LMC planetary nebulae.

For preprints, contact zijlstra

VLA Measurements of a sample of Planetary Nebulae

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We report on new radio measurements of Galactic planetary nebulae, aimed at resolving the controversies on the reliability of older VLA flux densities and the suggested deviations from the standard Galactic extinction law found for planetary nebulae. We show that for faint (<10 mJy) objects observed at high angular resolution, previous determinations are indeed too low. For the bright objects we find no significant differences. The new values are the most accurate flux determinations yet for planetary nebulae, reaching 1% for the brightest objects in the sample. Based on the new data, we confirm that there is a systematic difference between the extinction derived from the radio/Hβ flux ratio and derived from the Balmer decrement, which led to the suggestion of deviations from the standard extinction law. However, final confirmation of this has to await the availibility of more, accurate measurements of the Balmer (and/or Paschen) lines.

For preprints, contact pottash

Three-Dimensional Structure of the Circumstellar Envelope of CRL 618 Based on the ^{13}CO $J = 1 - 0$ Mapping Observations

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The circumstellar envelope of the carbon-rich star CRL618 has been mapped by the ^{13}CO $J = 1 - 0$ transition with a resolution of about $5.0'' \times 4.3''$ with the Nobeyama Millimeter Array. Emission is extended in size by about $10''$ and the distribution is approximately spherical. No strong elongation of ^{13}CO features along or perpendicular to the bipolar axis has been observed. Combining with the ^{12}CO $J = 1 - 0$ data that was taken before, we have created three-dimensional (3-D) density and temperature profiles of the CRL 618 circumstellar envelope. For creating the 3-D model, it is assumed that the expansion velocity is constant and the large-velocity-gradient model is applicable. The former ^{12}CO observations show that the envelope of CRL 618 consists of complex features. On the basis of the present ^{13}CO observations, these features are interpreted as the temperature and density irregularities in the outer circumstellar shell. The comparison of the present results with the model density profile given by optical light-scattering maps is made.

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Dissertation Abstracts

Hydrodynamics and Dust Formation in the Circumstellar Shells of Miras and Long–Period Variables

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Miras and Long–period Variables (LPVs) are highly evolved stars on the Asymptotic Giant Branch. Due to the peculiar physical conditions of these luminous pulsating objects, their cool, extended atmospheres are distinguished sites for the formation of small solid particles (dust). A massive outflow or wind develops, which is driven by radiation pressure on dust. Dust particles influence both, the internal structure of the circumstellar shell as well as the optical appearance of Miras and LPVs. A thorough description of the circumstellar dust shells (CDS) around Miras and LPVs is necessary for a comprehensive understanding of this important stage of the cosmic cycle of matter.

The CDS around Miras and LPVs have to be considered as complex nonlinear systems, which require a consistent treatment of hydrodynamics, dust formation, thermodynamics, and chemistry to achieve a reliable model description. Hence, dynamical models of CDS around carbon–rich Miras and LPVs are presented, which include, consistently coupled, time-dependent hydrodynamics and a detailed treatment of the processes of formation, growth and evaporation of dust grains as well as radiative transfer and a treatment of the chemistry of the gas phase.

The results stress the necessity of taking into account the relevant physical interactions. Thereby, the dust complex is revealed as the decisive component which dominates the dynamics of the CDS. Radiation pressure on dust, supported by the interior pulsation, is shown to drive the wind, but moreover, the dust complex is able to induce its own strong shock waves which travel through the atmosphere and predominate the circumstellar

structure. Furthermore, due to this mechanism of *dust–induced shocks*, the radial structure of the CDS appears to have a discrete or onion–shell like structure, which also results in an inhomogeneously distribution of the dust grains.

The abundance ratio of carbon to oxygen turns out to be a key parameter for the model calculations. For sufficiently high values of the carbon overabundance the time scale of the CDS behaves in accordance with the time scale of the interior pulsation. However, if the overabundance of carbon is reduced the CDS develops a separate time scale, multiple times longer than the pulsational time scale, an effect which we call *multiperiodicity*. Furthermore, an increase of the abundance of carbon to oxygen results in an increased outflow velocity. As a result of this linear correlation the derivation of carbon overabundances from the measurement of final outflow velocities becomes, in principle, possible. A direct derivation of the photospheric overabundance from observations is a difficult task, which has been possible only for a rather limited number of objects.

For sufficiently luminous models an instability occurs. In this work this new effect is called *exterior κ–mechanism* since the dust opacity plays the key role. In these models, radiation pressure on dust induces strong shocks, even in the absence of an interior pulsation. The absorption of stellar radiation by the dust particles causes an acceleration of the material, and moreover, the generation of small amplitude waves in the inner dustfree region, due to the backwarming of the dust. In turn, these waves trigger dust formation and impose a time scale on the dynamical system, and thus they close the cyclic self–maintaining process.

Dust–induced shocks as well as multiperiodicity are shown to influence decisively the optical appearance of the dust shell models by effects, which, in principle, are also present in observations of the objects under consideration.

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A study of the space distribution of Stars on the Asymptotic Giant Branch in our Galaxy

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The IRAS Point Source Catalog is likely to include almost all stars on the Asymptotic Giant Branch (AGB) with thick dust and gas envelope of our Galaxy. However, with the IRAS fluxes alone, it is difficult to determine their type and to estimate their distance. Their number and space distribution is still not well known. To solve this problem, a solution is to combine near infrared photometric data with IRAS data: to sort out carbon stars such as IRC+10°216 or infrared carbon stars (IRCS) from oxygen rich stars in a wide range of the thickness of the circumstellar dust envelopes and to allow a good estimate of their total fluxes received at the Earth and thus to the distance of IRCS.

I measured the near infrared fluxes of more than 2000 IRAS stars selected to observe the largest number of carbon stars. More than 100 new IRCS candidates (about 20% of all known IRCS) are recognized. The carbon rich nature of most of these candidates is confirmed with the help of IRAS spectra not still published and for all candidates observed in optical spectroscopy. By analysing the photometric data of IRCS, I obtain a scale height of 190 pc, show that their density is independent of the galactocentric distance in the range 5–14 kpc, deduce a value of about 12 stars/kpc^2 (25 % of all carbon stars) and a total mass loss rate of $\sim 10^{-4} M_\odot$/kpc^2/year du mainly to stars with thick envelope. Finally, I identify a group of M stars having same IRAS colours as IRCS but near infrared colours indicating a temperature of about 4000K. Optical spectroscopic data that I obtained show that these stars are M7, M8 or M9 giants.

I use these new determinations to include AGB stars in a synthetic model of stellar populations ("Besançon" model) that I extend in the infrared. The comparison with star counts in the K and IRAS bands allows to constraint the AGB ages and the density of oxygen rich stars with thick envelope.

Finally, I apply the methods established in this dissertation to show the interest of the near infrared southern sky survey (DENIS) to study AGB stars.

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