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Abstracts of recently accepted papers

Visual *versus* near–infrared variability of R For: evidence for a multiperiodic circumstellar modulation

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Long–term AAVSO visual observations and near–infrared data on the carbon–rich long–period variable star R For have been analyzed. We find that the Fourier development of the light curve depends on the observation wavelength. For most components – including the main one – the amplitude decreases from the visible to the near–infrared. The most sensitive components to the band correspond or are related to frequencies that are close to subharmonics of the main periodicity. We propose that this may be the result of a multiperiodic modulation of the light curves due to circumstellar dust shells, as predicted by theoretical models.

Accepted by the Astronomical Journal

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The anomalous SiO maser transition v=2 J=2–1

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We present high-sensitivity observations of the SiO transition v=2 J=2–1, which is known to present anomalous maser emission, together with simultaneous observations of the v=1 J=2–1 intense maser. Only 3 stars were previously detected in the v=2 J=2–1 transition. We present 8 new detections (out of a total of 10 detected stars) and significant upper limits for 37 other stars, which allows for the first time a statistical study of this maser transition. The unexpectedly weak emission in this line is confirmed. There is also a clear trend favoring the emission of the v=2 J=2–1 line in S-type stars, with respect to O-rich sources (that are the most common emitters in the other SiO lines): the v=2/v=1 J=2–1 line ratio is at least 10 times larger in S-type stars than in M-type sources. We also find a trend of the v=2 J=2–1 emission to be relatively red-shifted, confirming a previous result for one source. The possible origin of these properties is discussed. We conclude that the mechanism previously proposed by Olofsson et al., introducing the effects of line overlap between one

ro-vibrational transition of SiO and another one of H_2O, can explain the observed peculiarities of the SiO v=2 J=2–1 line.

Accepted by Astronomy and Astrophysics

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On the gas temperature in the shocked circumstellar envelopes of pulsating stars

I. Radiative heating and cooling rates

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Radiative heating and cooling in the circumstellar envelopes of cool stars is investigated, considering gas densities of $10^{4\cdots14}$ cm^{-3} and gas temperatures of 500 ... 20000 K. Various heating and cooling processes are included: rotational and ro–vibrational transitions of polar molecules and of H_2, atomic line transitions, bound–free transitions, free–free transitions and photochemical reactions. Theoretical concepts and computational methods are worked out, which on the one hand can account for important non–LTE effects and radiative trapping and on the other hand allow for a fast and proper inclusion of these heating and cooling rates into time–dependent hydrodynamical model calculations.

Radiative cooling timescales for a carbon–enriched gas typical for C–star atmospheres are calculated, and the thermal relaxation of the gas after the passage of shock waves is discussed. A gradual transition of the character of the propagating shock waves is expected to occur at densities around $10^{6\cdots8}$ cm^{-3}, changing from predominantly isothermal to predominantly adiabatic with decreasing gas density.

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On the gas temperature in the shocked circumstellar envelopes of pulsating stars

II. Shock induced condensation around R Coronae Borealis stars

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A physical mechanism is presented, which may be essential for the occasional onset of dust formation in the circumstellar envelopes of pulsating R CrB stars.

We study the thermal energy balance, the chemistry and the nucleation in fixed fluid elements of the circumstellar envelopes around R CrB stars, which are periodically hit by strong shock waves caused by the stellar pulsation. Non–LTE radiative heating and cooling via free–free, bound–free and atomic line transitions and via rotational and ro–vibrational transitions of polar molecules is taken into account. After the heating and compression due to an outrunning shock, the considered fluid element first radiates away its excess of internal energy, and then reexpands according to the periodicity, which is a typical feature in such pulsating envelopes. This reexpansion causes adiabatic cooling. Within a particular range of the gas particle densities $n_{<He>} = 10^{7\cdots10}$ cm^{-3}, this finally causes substantial lower gas temperatures than in radiative equilibrium.

Thus, the preconditions for effective carbon nucleation (high densities and low gas temperatures for a sufficiently long time) may be temporarily present quite near to the photosphere of a pulsating R CrB star. The presented mechanism leads to gas temperatures as low as 1500 K already outside of a radial distance of only $1.5 - 3$ R$*_*$, despite of the high effective temperatures of R CrB stars.

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AGB stars: densities and formation rates obtained from OH/IR stars

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We determine densities and star formation rates of AGB stars from an analysis of OH/IR stars in the solar neighbourhood. The stars are divided into three distinct mass ranges corresponding to the precursors of type I, II and III planetary nebulae, according to the Peimbert classification scheme. The adopted distance scale is based on the period-luminosity relationship by Feast et al. (1989). The formation (or death) rates are calculated using stellar evolution models for AGB stars, and are compared with the corresponding rates for planetary nebulae and white dwarfs. The results indicate that both surface and volume densities of AGB stars are in good agreement with previous determinations in the literature. The formation rates are found to be very sensitive to the evolution time at the AGB, and depend also on the adopted model.

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Quadrupolar Planetary Nebulae, a new Morphological Class

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In the context of the IAC morphological survey of Galactic planetary nebulae (PNs) a new morphological class has been found, and we define their members as quadupolar PNs. We have found five quadrupolar objects whose lobes are, in pairs, symmetric with respect to two different axes. Among these PNs, three (M 2–46, K 3–24 and M 1–75) have well–defined pairs of lobes; another two (M 3–28 and M 4–14) are irregular and very possibly quadrupolar. For M 2–46 we have measured the extension and the angle between the lobes, and the expansion velocities of the lobes by means of spectroscopic analysis. We propose that these nebulae have been formed by precession of the rotation axis of the central stars, possibly in the presence of a binary companion, associated with multiple shell ejection at the Asymptotic Giant Branch (AGB). A simple binary mechanism non-associated with precession cannot produce such a morphology.

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Manuscript is available by ftp at iac.es, anonymous, /pub/amt/96_15055.tar.gz

Circumstellar HCN Emission from Two Unusual Carbon Stars: IRC+10401 and AFGL2233

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Interferometric observations of HCN (J=1–0) emission from the circumstellar envelopes of two enshrouded carbon stars have been performed. The two stars, AFGL2233 and IRC+10401, are unusual because of their strong HCN emission and high outflow velocities. We find that the emission regions are relatively compact and that there is no evidence of asymmetry these outflows. The emission region aound AFGL2233, a star which is believed to be at a larger distance than IRC+10401, was not resolved by a 5.9″ x 5.1″ beam, although an undetected extended component may exist. The emission region of IRC+10401 was resolved by a 5.1″ x 4.6″ beam, and we estimate a deconvolved source size of about 8.6″. This indicates a linear size greater than that expected from models of photodissociation by interstellar ultraviolet. Comparing these sizes to the CO emission region sizes indicates that the circumstellar envelopes are dissociation-bounded.

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Optical observations of southern planetary nebula candidates

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We present Hα+[N II] images and low resolution spectra of 16 IRAS-selected, southern planetary nebula candidates previously detected in the radio continuum. The Hα+[N II] images are presented as finding charts. Contour plots are shown for the resolved planetary nebulae. From these images mean optical angular diameters were determined. Optical spectra show that these IRAS-selected and radio detected planetary nebula candidates are indeed planetary nebulae. The values for their extinction coefficient is generally very high. More than half of the PN seem to be of low excitation, having central stars with an effective temperature of probably $\sim$60,000 K or less.

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Kinematics of Molecular Gas in the Proto-Planetary Nebula CRL 2688 (The "Egg")

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We present aperture synthesis images of the HCN J=1-0 emission line toward the proto–planetary nebula CRL 2688 (the "Egg Nebula"). The images were obtained with the BIMA mm-interferometer, and have angular and velocity resolutions of 3" and 1.3 km s^{-1}. The emission is well-resolved spatially and is extended mainly in the east–west direction, coincident with the optical dark lane. There are also extensions of the HCN emission to the north and south, along the symmetry axis of the optical bipolar nebula. The north–south extensions are not consistent with predictions of photodissociation models for HCN. The morphology of the HCN maps shows a striking correspondence with the 4 bright lobes of the S(1) line of H_2, which lie at the ends of the extended HCN emission. The velocity centroid of the HCN J=1-0 line shows a significant gradient across the nebula. The magnitude of the gradient is larger than was found in previous work, attributable to improved angular resolution. The most blue–shifted emission is to the north and east of the central star, while the most red-shifted emission is to the south and west. The steepest gradient lies along a line intermediate between the bipolar axis (at p.a. 15^o) and the dark equatorial lane (p.a. 105^o). The gradients along each of these two axes are nearly equal, with a value of 0.9 km s^{-1} arcsec^{-1}. We suggest that the observed velocity gradient may be attributed to 2 kinematic components: (1) a radial outflow in which the velocity along or near the bipolar axis

exceeds the flow velocity in the equatorial plane by at least a factor of 1.5; and (2) a rotational component in the equatorial plane. The implied specific angular momentum in the rotational component to the gas motion could be supplied from the orbital angular momentum of a binary companion. We discuss some possible mechanisms for transferring angular momentum, and argue that gravitational torques are unlikely to be effective enough to produce the observed velocity gradient, but that magnetic fields, acting through Alfven waves, could do so if the stellar surface field is sufficiently high (of order several kilogauss).

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Molecular Hydrogen Morphology, Kinematics and Excitation in AFGL 2688 and NGC 7027

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We report the first results of spectro-imaging post-AGB objects in the near-infrared K' band using a new instrument called *BEAR*. This instrument has been used to obtain high spatial ($0.6''$) and spectral (~ 40 km s^{-1}) resolution observations of the proto-planetary nebula AFGL 2688 and the young planetary nebula NGC 7027. The current paper is devoted to a detailed study of the morphology, velocity field, and excitation of H2 in their circumstellar envelopes.

In AFGL 2688, the H_2 emission shows four bright clumps forming a remarkable cross-like pattern with weaker H_2 emission connecting the north and east, and the south and west clumps, respectively. No trace of lines or continuum from ionized gas is seen in the spectra. The continuum emission seen in the central parts of the nebula is stellar light scattered by nebular dust. The velocity field shows that the northern and eastern clumps are blue-shifted whereas the southern and western clumps are red-shifted with respect to the systemic velocity. There is also evidence for significant velocity gradients across the H_2 structures. The emission of the H_2 lines in AFGL 2688 is consistent with shock excitation.

In NGC 7027 new morphological details are revealed by the observations. The emission from the inner envelope is dominated by continuum and line emission from the ionized nebula, including strong Brγ, HeII and HeI lines. The H_2 emission is distributed at the periphery of the ionized gas, along a four-lobed clover pattern with an equatorial torus which is seen for the first time in its entirety. The H_2 velocity distribution demonstrates that the kinematics of the hot gas traced by H_2 is firmly linked to the outer molecular envelope. The H_2 emission in NGC 7027 is consistent with excitation in the UV photon dominated region (PDR) at the interface of the ionized and molecular gas.

The morphology and excitation of H_2 in AFGL 2688 and NGC 7027 are consistent with an evolutionary scheme winds during the proto-planetary nebula phase develop strong shocks in the slower expanding AGB envelope and are able to excite the H_2 emission, and in the young planetary nebula phase ultraviolet radiation from the hot, central star ionizes the inner cavity and excites the molecular hydrogen in the PDR.

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A Nex Maximum Likelihood Method for Luminosity Calibrations

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A new statistical parallax method using the Maximum Likelihood principle is presented, allowing the simultaneous determination of a luminosity calibration, kinematic characteristics and spatial distribution of a given sample.

The new method has been developed for the exploitation of the HIPPARCOS data and presents several improvements with respect to the previous ones: the effects of the selection of the sample, the observational errors, the galactic rotation and the interstellar absorption are taken into account as an intrinsic part of the formulation (as opposed to external corrections). Furthermore, the method is able to identify and characterize physically distinct groups in inhomogeneous samples, thus avoiding biases due to unidentified components. Also, the implementation used by the authors is based in the extensive use of numerical methods, so avoiding the need for simplification of the equations and thus the biases they could introduce.

Several examples of application using simulated samples are presented, to be followed by applications to real samples in forthcoming articles.

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Absolute Magnitudes and kinematics of Oxygen Miras Variables

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A new maximum likelihood method, using apparent magnitudes, proper motions and radial velocities, has been applied to a sample of 90 Mira stars extracted from the HIPPARCOS Input Catalogue (INCA) to determine absolute magnitudes and kinematics. Using this new method three different groups of Mira stars have been identified in the sample, with different luminosities, kinematics and scale height. Two of them are well determined and are identified respectively with the old disk population and the extended thick disk-halo population. The third one is too small and peculiar and its identification has to be left for further studies.

Using these results the stars of the sample are discriminated into the groups and their distances are estimated. These distances are compared with other independent determinations obtained from K-band and near-infrared narrow photometry.

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Discovery of the C_8H radical

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Searching for C_7H and C_8H in the carbon star envelope IRC+10216, we have identified 10 lines with harmonically related frequencies and with regularly increasing intensities. The rest frequencies can be closely fitted with the

standard expression for the energies of a linear molecule with a rotational constant B = 586.676 MHz, a distortion constant D = 6.3 Hz, and half-integer quantum numbers J. The value of B is within 0.1% of that predicted by Pauzat et al. (1991) for the $^2\Pi$ ground state of C_8H and the value of D typical of a linear acetylenic chain of C_8H's weight. Since the half-integer J numbers are also consistent with a $^2\Pi$ state, we concluded that we had very probably discovered C_8H. The non detection of Λ-doubling as well as of a second series of lines corresponding to the other fine structure state, suggested that the C_8H ground state is inverted and that we were observing the $^2\Pi_{3/2}$ state.

Our identification is now confirmed in the laboratory: M. Carthy et al. (1996) just succeeded in detecting 30 millimeter lines arising from the new radical in an acetylene discharge and confirmed that their carrier is indeed C_8H.

The rotation temperature diagram of the C_8H lines observed in IRC+10216 yields a rotation temperature T_{rot}= 52 K and a beam-averaged column density $N = 5.5\,10^{12}$ cm^{-2}. This latter is a factor of 30 lower than the column density of C_6H; it is similar to the column density predicted by Millar & Herbst (1991) in the case of a medium-large acetylene abundance ($[H_2C_2]/[H_2]= 2.5\ 10^{-5}$)

We found no trace of C_7H in either the 30-m telescope, or the 45-m telescope data.

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SiO maser sources in the outer disk of the Galaxy

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The observations in the ^{28}SiO J=1-0 v=1, J=1-0 v=2 lines and the ^{29}SiO J=1-0, v=0 line were simultaneously made towards 181 color-selected IRAS sources in the outer disk of the Galaxy (at longitudes between 90° and 250°). The ^{28}SiO lines were detected in 63 sources (56 new) and the ^{29}SiO line in 11 sources (9 new). Most of the detections are optically variable stars, mainly Mira-type variables and a few semi-regular variables. The detection rate(35%) is much lower than that of the bulge survey performed by the same observational system, the 45m telescope at Nobeyama Radio Observatory. The lower detection rate of SiO maser emission is partly attributed to the increase of contaminations by stars with C-rich circumstellar envelope and young stellar objects in the outer disk sample. The kinematical implications of the observational results are also discussed. The luminosity distances to the SiO maser sources are estimated from their IRAS fluxes at 12 micron and colors. By combining the SiO radial velocity and the luminosity distance, the rotation curve of the outer Galatic disk is found to be slightly falling within the galactocentric distance between 8.5kpc and 12kpc. The sources located within 20° from the Galactic anticenter direction are used to check for a peculiar motion of the local standard of rest.

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Messages

ASTRID :
Advanced Stars : a Tool for Relating Informations and Data

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Jobs

Postdoctoral position at Columbia University

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We are searching for a postdoctoral scientist to aid in the research on the circumstellar and interstellar environment of Supernova 1987A. The work would include completed, ongoing and planned observations of SN 1987A and its surroundings including data from IUE, UIT, ISO, HST and various ground-based observatories, plus preparation for observations with future ground, airborne and space-based instruments. Topics of concern include mapping the circumstellar nebula of the SN and the interstellar medium of the 30 Doradus region using light echoes, detailing the composition, density and velocity structure of the circumstellar envelope, analyzing the polarimetric and photometric properties of surrounding dust, measuring the reflected ultraviolet flux from SN shock breakout, and observing the interaction between the SN ejecta and circumstellar envelope and the formation of Supernova Remnant 1987A. W e are looking for excellent candidates practiced in some of the above observational techniques and knowledgeable concerning circumstellar and interstellar processes. The person selected will be encouraged to study the above problems as well as to develop his or her own related investigations, with support for observation, publication and travel to professional meetings.

The position is available for one year with the possibility of extension to up to three years, with a start date in early 1997 subject to the initiation of funding. Applicants should provide a curriculum vitae, summary of research, and names of three colleagues willing to write letters of reference, **by 1 July 1996** to the address above.

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