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Abstracts of recently accepted papers

He 2-25, Th 2–B, 19W32: further links between bipolar planetary nebulae and symbiotic stars?

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Optical spectroscopy of the highly collimated bipolar nebulae He 2–25, Th 2–B, and 19W32 is presented.

He 2–25 and Th 2–B are found to have very dense ($N_e \sim 10^7$ cm^{-3}) cores characterized by emission lines of low to intermediate ionization species, including rich [FeII] emission. The Hα profiles present broad non–gaussian wings. These spectral characteristics are common to a sub–class of bipolar planetary nebulae (PNe), including the well studied M 2–9, and closely resemble those of interacting binary systems such as symbiotic stars.

The core spectrum of 19W32 shows only Hα and [NII]λ6583 in emission, and is dominated by a stellar continuum from a relatively cold star whose classification is tentatively given between K0 and M2. Providing a better classification and determining whether this star is indeed physically associated with the nebula would be important to understand the nature of these objects and to test the hypothesis of binarity for the formation of bipolar planetary nebulae.

The possible classification of this class of objects as proto–PNe or symbiotic stars is discussed.

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Modelling the structure of selected planetary nebulae

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Theoretical line profiles are calculated and fitted to the observed ones in order to analyse the velocity and density distribution in several observed planetary nebulae. The new approach to this problem is described and the new results for three well known nebulae are presented. Some suggestions concerning plasma diagnostics in planetary nebulae are drawn.

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Comparative study of a [WC 6] nucleus with other emission-lines nuclei of planetary nebulae

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The central star (CSPN) of the planetary nebula M 1-25 (PN G 4.9+4.9) is classified as a [WC 6] star, the only CSPN of this subclass known at this time. A comparison with the other emission-lines CSPN (the [WC]-class and the 'weak emission-lines stars' or *wels*-class) shows that (1) the characteristics of this [WC 6] star fit well inside the main properties of the other [WC] CSPN ; (2) the [WC] CSPN seem to evolve from the [WC 8-11] (latter) to [WC 2-4] (earlier) subclasses, say from dense nebulae with cool stars to more extended nebulae with hot nuclei, as for other CSPN ; (3) on the two-colour IRAS diagram, the [WC] and the *wels* CSPN form two different groups : the progenitors of the [WC]-type CSPN seem to be Carbon stars evolving along post-AGB tracks, whereas the *wels* CSPN seem to be related to OH/IR stars, some of them having possibly experienced a late helium-flash.

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SiO maser survey of the galactic bulge IRAS sources: III. Kinematics of the bulge stars.

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We have surveyed IRAS sources toward the Galactic bulge in the SiO J=1-0, v=1 and 2 transitions. The sources were selected from the IRAS Point Source Catalog on the basis of the IRAS 25/12 mm flux density ratio, extracting dust enshrouded objects at distances of 8 kpc. SiO masers were detected in 79 of the 129 sources we surveyed in the region of $|l| < 15°$ and $3° < |b| < 15°$ (excluding the strips of $4° < |b| < 5°$ and $7° < |b| < 8°$) . The sources are divided into disk and bulge members based on the observed infrared luminosity. The SiO maser properties of the present sample are quite similar to the maser properties of the SiO sources that were found in the strips of $|b| = 4 - 5°$ and $7 - 8°$ in previous studies. A full discussion of the radial velocities of the entire bulge SiO maser sources is given. Rotation curve analysis shows that the radial velocities of the northern sources are systematically shifted from the radial velocities of the southern sources. If this shift is interpreted as being due to a tilt of the rotation axis of the bulge, the tilt angle is derived to be about 7 degrees from the galactic longitudinal circle. After correcting the effect of the tilt on the radial velocities, we obtain an average shift of the radial velocity of -17.7 +- 7.6 km s-1 at zero galactic longitude for the bulge sources. For the disk sources, in contrast, we get an average shift of the radial velocity nearly equal to zero . This fact indicates that (1) the local standard of rest is moving toward the galactic center direction, or/and , (2) a streaming motion of stars in the galactic bulge is observed. The velocity dispersion of the bulge sources in the rectangular area of $|l| < 4°$ and $|b| < 5°$ is found to be about 110 $km.s^{-1}$. The dispersion of the bulge sources in the remaining area is about 70 $km.s^{-1}$, which is close to the dispersion of $60 - 70$ $km.s^{-1}$ of disk stars. Several forbidden regions (holes) are recognizable in the l-v map of sampled stars; for particular ranges of radial velocities no star can be found at some galactic longitudes. The positions of such holes in the l-v map correspond to the contour dips in the HI l-v map taken at the low galactic latitude ($|b| < 3°$). This may be evidence for complex streaming motion of stars resulting from a bar structure in the Galactic bulge.

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The first 8-13 μm spectra of AGB stars in the Magellanic Clouds

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We have obtained 8-13 μm spectra of two AGB stars in the Magellanic Clouds (MCs), and report the first detection of dust features in AGB stars in the MCs. The long period variable (LPV) TRM60 (P = 1260 days) in the LMC displays silicate absorption, and the LPV GM103 (P = 1070 days) in the SMC shows silicate emission. The presence of silicates confirms previous observations using different techniques that these stars are oxygen-rich. By modeling the spectral energy distributions and 8-13 μm spectra with a dust radiative transfer model we find that although the two stars have similar high luminosities their dust optical depths differ by a factor of 10.

A similar analysis was carried out for a Galactic OH/IR star of comparable period. The results for these three stars suggest that the mass loss rate increases with metallicity in AGB stars.

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CO and HCN observations of carbon stars

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We present CO and HCN observations of carbon stars. They consist of partly new detections in the ^{12}CO J = (1-0), (2-1) and HCN(1-0) lines obtained with the SEST and the IRAM telescope, and of ^{12}CO and ^{13}CO J = (1-0), (2-1) and (3-2) observations with IRAM and the JCMT of some of the infrared brightest carbon stars.

Recently, Bujarrabal et al. (1994a,b) proposed a critical value for the ratio of the integrated intensities HCN(1-0)/^{12}CO(1-0) to distinguish between carbon stars and oxygen-rich stars. In four carbon stars we find ratios consistent with their borderline value, and in two cases HCN/CO ratios below their suggested borderline value in stars which are almost certainly carbon stars. The apparent discrepancy may lie in the fact that the critical line ratio in Bujarrabal et al. is derived for the 30m IRAM telescope, while our ratios are derived from 15m SEST data. The difference in beam size may result in slightly different excitation regions being sampled.

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Observing and Modelling Envelopes of Post–AGB Stars

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The goal of this paper is to derive the physical properties of the dust envelopes around the post-AGB stars IRAS 10215−5916, 16342−3814, 17150−3224, and 19500−1709 by means of radiative transfer calculations. The theoretical spectral energy distributions (SEDs) have been compared with observational data for the wavelength range from 0.4 to 1300 μm. We were able to obtain a very satisfactory match between our model SEDs and the observational data. As a result, we have derived estimates of the inner and outer radii, the density, the

temperature, and the mass of the circumstellar shells of the four objects. For IRAS 16342−3814, 17150−3224, and 19500−1709 the emission observed at submillimetre and millimetre wavelengths can be accounted for either by a single shell and a dust emissivity that follows a power law $Q_\lambda \propto \lambda^{-0.7}$ for $\lambda \geq 230$ μm or by assuming the presence of a second shell located outwards from the shell responsible for the 10–100 μm radiation.

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Radio Frequency Continuum Emission from Evolved Stars

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The evolution of stars between the AGB and planetary nebula phases was investigated by sensitive radio continuum observations of a sample of 21 evolved stars with high mass loss rates and extended circumstellar envelopes, in a search for newly formed compact planetary nebulae. Four were found: two (CRL 618 and IRAS 21282+5050) are well known young planetary nebulae while the other two (IRAS 17423-1755 and CRL 915, the 'Red Rectangle') are new detections. These recent observations show that the radio frequency flux of CRL 618 continues to increase. The strength of the radio continuum emission from CRL 915 gives a type of B3 or earlier for the exciting star.

Radio continuum emission was detected from four more stars in the sample at an intensity too weak to be due to compact planetary nebulae but too strong to be photospheric. These stars may have extended partially ionized chromospheres.

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Imaging Polarimetry of Proto-planetary and Planetary Nebulae

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Imaging polarimetry maps are presented for a sample of bipolar proto-planetary and planetary nebulae. Each of the highly polarized proto-planetary nebulae possesses a 'polarization disc' which has been observed more frequently in nebulae associated with star forming regions. In order to account for the observed high levels of polarization in proto-planetary nebulae we consider the effects of a thin coating of a volatile material on refractory grains with an original size distribution typical of the interstellar medium.

The planetary nebulae are seen in a mixture of reflected and emission light and their polarization patterns suggest that, in many instances, they are emission nebulae surrounded by an extensive envelope of reflection nebulosity.

The origin of the skew-symmetry and ansae in the isophotal maps of proto-planetary and planetary nebulae are discussed in terms of binary stars and magnetic fields.

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Faint carbon stars in the Small Magellanic Cloud. II

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We have obtained JHK photometry for 50 carbon stars in the Small Magellanic Cloud and medium- dispersion spectra for 37 of them. 39 of the stars have $K > 13$ mag. M_{bol} and log T_{eff} are derived from $(J-K)_0$ with the aid of available relations. The least luminous star has $M_{bol} \sim -1.8$ mag; most of the stars are rather warm. The faint end of the M_{bol} range of the SMC C stars falls well below the lowest luminosity observed so far for C stars in Local Group dwarf spheroidals. Most of the stars with $M_{bol} < -2.7$ mag appear to be on the post-flash side of the locus for the onset of the first helium flash in double shell sources; for the fainter ones the choice between this mechanism or another one, so far unknown, is still open.

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Dissertation Abstracts

Multiwavelength studies of selected post-AGB stars

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Thesis work was conducted at the Astronomical Institute of the University of Utrecht and the Space Research Organization of the Netherlands (SRON-Utrecht)

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I. Molecules in the optical spectra of post-AGB stars
I have studied molecular absorption (C_2, CN and CH^+) and emission (CH^+) bands in the optical spectra of twelve post-AGB stars. A detailed study on the molecular spectra showed that in all cases the lines are formed in the AGB remnant. The presence of these molecular bands allows an accurate determination of the AGB expansion velocity. But more important is our finding that modeling the excitation of the C_2 molecule allows the determination of the AGB mass-loss rate, without knowledge of the distance from the line forming region to the central star, nor the molecular abundance. From the molecular column densities and dust inner radius we derive mass-loss rates of the order of $-4.3 \leq \log \dot{M}_{mol} \leq -6.4$. The mass-loss rates derived by modeling the relative population over the rotational levels of the C_2 $X^1\Sigma_g^+$ $(v'' = 0)$ state, are in the range $-3.0 \leq \log \dot{M}_{exc} \leq -1.9$. This is significantly larger than the mass-loss rates derived from CO millimeter line emission. Further study on the excitation of C_2 is needed to solve this controversies. We have found a relation between the C_2 molecular column densities and the expansion velocity. This is interpreted as due to the fact that carbon rich dust is more efficiently accelerated by the radiation field of the star.
II. A study of HD 101584, HR 4049 and HD 56126
HD 101584: We have investigated the optical photometry and showed that it has a periodicity of 218 days. A detailed analysis showed that the photometric periodicity is due to changes in the Balmer discontinuity. The Doppler velocities of the central B stars shows radial velocity variations which also seem to be periodic on 218 days. Both the photometric and radial velocity variations can be understood if there is a nearby companion

star which is so close that it can change the wind structure of the primary. Due to this nearby secondary the mass-loss rate of the primary is much higher than expected for a normal post-AGB star. The radiation field of the central star cannot support the ionization degree of the stellar wind and we observe a spectrum of the central star, B(e)8-9I, and a much cooler shell spectrum from the stellar wind.

HR 4049: We have analyzed the optical spectrum and found numerous lines of hydrogen, carbon, nitrogen and oxygen, but not a single line from a metal. We confirmed the detection of HeI and are the first to present the detection of circumstellar [OI] emission. A remarkable discovery was our finding of the time variability of the NaI D lines. This time variability is interpreted as due to the orbital motion of the star within an almost edge-on circumsystem disk.

HD 56126: We have looked at reported short time variations of the Hα profile. This is an important question with respect to the origin of the emission in the Hα profile and could possible be used to discriminate between a photospheric or circumstellar origin. From our analysis we find that Hα vary on a time scales of months. Together with our finding that all absorption lines are asymmetric we interpret this as due to pulsation.

Copies of my thesis are for free available upon request