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Abstracts of recently accepted papers

IRAS 17423−1755: a massive post-AGB star evolving into the Planetary Nebula stage?

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IRAS 17423−1755 has been recognized as a new bipolar nebula during a multi-wavelength observational program of unidentified IRAS sources with far infrared colours similar to those of known planetary nebulae.

B, V, R and Hα CCD images show a clearly marked bipolar structure with a total extension of $\sim$ 11 arcsec. The spectrum of the core shows strong emission lines of HI (Balmer and Paschen series), HeI, FeII, [FeII], OI, CaII and [CaII]. Strong P-Cygni profiles are clearly seen in the Balmer lines and in some other emission lines, indicating the presence of a strong mass outflow. This is confirmed by the presence of a very steep density gradient in the nebula, strong near infrared excess and the detection of highly symmetric bipolar emission at very large velocities in the lobes ($\gtrsim$ 425 km s^{-1}).

The highest velocity, however, is observed in the innermost region of the bipolar outflow, where a jet–like structure is detected with v = 870 km s^{-1}, while its velocity decreases to 750 km s^{-1} a few arcsecs away from the central star. This has been interpreted as the result of sporadic mass loss events with a time-dependent ejection velocity. The position-velocity diagram is well reproduced assuming an inclination angle of 150°. The emission observed in the lobes shows an extraordinary line width and double–peaked profiles, indicating that the emission arises from the cooling region behind a bow–shock.

From the high values of the [NII]/Hα ratios, we deduce that the outflowing material is nitrogen enriched gas of stellar origin, which can only be explained if IRAS 17423−1755 is an evolved star and not a young stellar object. The morphology and kinematics closely resemble those observed in well known bipolar proto-planetary nebulae, while the luminosity is far below the values found in known LBV's (Luminous Blue Variables). The characteristics of the OH maser emission found in IRAS 17423−1755 are consistent with the presence of an equatorial disk of neutral material (perpendicular to the bipolar axis) expanding at v$_e$ = 50 km s^{-1}, which could be the responsible for the collimation of the outflow.

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Circumstellar dust shells around long-period variables IV. Brightness profiles and spatial spectra of C-stars

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Theoretical brightness profiles and spatial spectra of dynamical models for circumstellar dust shells of long–period variables are presented.

Based on dynamical models of circumstellar dust shells, which include time–dependent hydrodynamics and a detailed treatment of the processes of formation, growth and evaporation of carbon grains, frequency–dependent radiative transfer calculations have been carried out which yield the synthetic brightness distributions and spatial spectra of these dust shell models.

The brightness profiles show a pronounced time–dependent internal structure on a spatial scale of a few stellar radii, which reflects the discrete shell–like distribution of dust across the circumstellar shell. Internal structures are also present in the synthetic spatial spectra (or visibilities) calculated from these intensity profiles. Similar structures, which are present in the observed brightness profiles and spatial spectra of several long–period variable stars can be physically explained by the formation of discrete dust layers resulting from the model calculations presented here. We also find temporal variations of the synthetic spatial spectra which are in quantitative agreement with respective observations. Our model calculations indicate, that the instants of time, when the minimum and maximum value of the visibility is reached depend on wavelength.

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Spectropolarimetry of the Bipolar Planetary Nebula M2-9

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We present optical spectropolarimetry of the young bipolar planetary nebula M2-9. The goal of these observations is to determine the origin of the knots or brightness enhancements seen in the lobes of M2-9. The line spectra of the lobes of M2-9 are composed of two components, one that is produced locally in the lobes and one that is scattered from deep in the nebula. The presence of this scattered radiation means that the total flux line ratios do not accurately describe the local conditions in the lobes. We have obtained spectropolarmetric data of the N2 and S2 knots and the adjacent nebula. We use our data to separate the scattered and unscattered emission line components.

From our scattered flux spectra, we determine that the reflected emission originates in the core of M2-9. At all of the positions in the North lobe we observe a broad wing on the scattered Hα line profile. We calculate the outflow velocity of the scatterers, $\approx$ 15 km s^{-1}, based on the observed wavelength shift between the Hα peak in scattered and unscattered flux.

Using the unscattered spectra, we derive the local line ratios as a function of position in the North and South lobes. The level of excitation of the spectra decreases in the off knot regions. We measure the gas temperature as a function of position and find that it is approximately constant across the lobes. This result rules out the simple recombination tail model proposed by Goodrich for the origin of the knots. Alternatively, we suggest that the off-knot positions are being ionized by a UV spectrum that is attenuated by material between the lobes and the central UV source. We have used the photoionization code CLOUDY to test this idea and find that attenuation affects alone cannot accurately reproduce the observed unscattered line ratios. To accurately model the observed line ratios in the knots, we require the presence of both high ($\geq 10^5$ cm^{-3}) and low ($\approx 10^3$ cm^{-3})

density components. For the off-knot positions both attenuation affects and multiple density components are necessary to reproduce the observed line ratios.

We modify the recombination tail model proposed by Goodrich to explain the origin of the knots in M2-9. We propose, as did Goodrich, that at discrete North - South levels, the lobes of M2-9 contain "rings" of higher density material. The UV source illuminates a section of the lobe causing these rings of material to glow, producing the knots and explaining and naturally leading to their "fixed" North - South positions. Obscuring material near the star keeps one side of the lobe from being illuminated by the full force of UV source, thus explaining the lower excitation off-knot spectra. This model can explain why the knots only appear to move in the East - West plane, while remaining fixed in the North - South direction. In addition, it explains why the observed spectra in the off-knot regions are lower excitation than the knot spectra.

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The Spectrum of BD +30 3639, 0.36 - 1.05 μm

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The dusty young, low excitation, planetary nebula, BD +30 3639, denoted as "Campbell's hydrogen envelope star" has been the subject of many investigations, particularly in the infrared wavelength region. We are concerned here with a high dispersion study of the optical spectrum. Detailed high spectral resolution observations of BD +30 3639 have been made at the center of the nebular image with a slit $1.''2 \times 4.''0$, for the wavelength region 3650$\AA$ to 10050$\AA$, using the Hamilton echelle spectrograph of Lick Observatory. This compact nebula has a density of about 10^4 atoms cm^{-3} and $T_\epsilon \sim 8800$ K. Its chemical composition does not seem to be remarkable; it resembles roughly that of Sun, although the luminous central star exhibits the spectrum of a classical carbon Wolf-Rayet type with $T_{eff} = 30,000$ K. It is suggested that the PN may brighten and rise in excitation as the central star evolves and grows hotter.

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Photoionization modelling based on HST images of Magellanic Cloud planetary nebulae: I. SMC N 2 and SMC N 5

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We have constructed fully self-consistent, detailed photoionization models for two planetary nebulae (PN) in the Small Magellanic Cloud (SMC), namely SMC N 2 and SMC N 5, to fit optical and UV spectrophotometric observations as well as HST Faint Object Camera (FOC) narrow band images taken in the light of Hβ. The derived density structure shows that both PN have a central cavity surrounded by a shell of decreasing density described by a parabolic curve. For both nebulae, our models fail to reproduce the HST images taken in the light of the [O III] λ5007 line, in the sense that the observed [O III] λ5007 surface brightness decreases more slowly outside the peak emission than predicted. An effective temperature of $T_{eff} = 111500$ K, a stellar surface gravity of $\log g = 5.45$ and a luminosity of $L_* = 8430\,L_\odot$ are derived for the central star of SMC N 2; similarly $T_{eff} = 137500$ K, $\log g = 6.0$ and $L_* = 5850\,L_\odot$ are derived for SMC N 5. SMC N 2 is optically thin and has a total nebular mass (H plus He) of 0.180 $M_\odot$, while SMC N 5 is optically thick and has an ionized gas mass of 0.194 $M_\odot$. Using the H-burning SMC metal abundance ($Z = 0.004$) evolutionary tracks calculated by Vassiliadis & Wood (1994), core masses of 0.674 $M_\odot$ and 0.649 $M_\odot$ are derived for SMC N 2 and SMC N 5, respectively. Similarly, from the He-burning evolutionary tracks of Vassiliadis & Wood for progenitor stars of

mean LMC heavy element abundance ($Z = 0.008$), we find $M_c = 0.695$ and 0.675 $M_\odot$ for SMC N 2 and SMC N 5, respectively. We find that Hβ images are needed if one is to derive accurate stellar luminosities directly from photoionization modelling. However, in the absence of a Hβ image, photoionization models based on [O III] images (and nebular line intensities) yield accurate values of T_{eff} and $log\, g$, which in turn allow reliable stellar masses and luminosities to be derived from a comparison with theoretical evolutionary tracks. We show that the correct nebular ionized mass can be deduced from the nebular Hβ flux provided the mean nebular density given by the C III] λ1909/λ1907 ratio is also known.

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On the status of planetary nebulae with WR-type nuclei

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A recent systematic search of Wolf-Rayet features in the spectra of Galactic planetary nebulae has increased the list of objects that are known to have WR-type nuclei to about 50. We have compared their nebular properties with those of the other planetary nebulae in the Galaxy. We have found that the nebular morphological types are similarly distributed in the two groups. Bipolar nebulae constitute only 20% of the total in each group. The distribution of the nebular abundance ratios N/O, He/H and C/O are the same in the two groups. The nebular expansion velocities are larger in the group of planetary nebulae with WR central stars. We argue that the WR phenomenon does not preferentially occur in more massive central stars of planetary nebulae, contrarily to what has been suggested in some former studies.

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Electronic copies via anonymous ftp from 158.75.11.4 , file /pub/hide/SKG/gs95.ps (or compressed version)

The Massive Post-Red Supergiants IRC +10420 and HD 179821

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The transition of a massive post-main sequence star from red supergiant to luminous blue variable or Wolf-Rayet star is a rapid and therefore rarely observed phase of evolution. We present evidence that the unusual yellow supergiants IRC +10420 and HD 179821 (= AFGL 2343) are undergoing such a transition. Polarimetric, coronagraphic near-infrared images reveal that each star is surrounded by an extended dust reflection nebula. These detections set IRC +10420 and HD 179821 apart from 89 Her, HD 161796 and several other luminosity class I stars that are thought to be descended from low-to-intermediate mass progenitors. The nebulae surrounding IRC +10420 and HD 179821 are very similar; each appears circularly symmetric, is detected out to $\sim 9''$ from the central star at 1.25 μm, and is unusually red for reflection nebulosity. The last result suggests that the dust grains in these envelopes are larger than typical of grains in the dust envelopes of low- and intermediate-mass evolved stars. Under the assumption that both stars lie at their kinematic distances ($\sim$ 6 kpc in each case), our images suggest each circumstellar envelope has a dynamical lifetime of $\sim$ 5000 yr, contains $\sim$ 5 $M_\odot$of gas and dust, and was likely ejected during a prior OH/IR supergiant phase. Thus, in addition to bolstering the post-red supergiant classification of both stars, these imaging results appear to place strong constraints on the evolutionary and mass loss histories of supernova progenitors.

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Deep Circulation In Red Giant Stars: A Solution to the Carbon and Oxygen Isotope Puzzles?

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The long-standing puzzle of low $^{12}C/^{13}C$ in low-mass red giant branch (RGB) stars, and the more recent puzzle of low $^{18}O/^{16}O$ ratios in asymptotic giant branch (AGB) stars and in circumstellar Al_2O_3 grains preserved in meteorites, can both be resolved by deep circulation currents below the bottom of the standard convective envelope. This transports matter from the non-burning bottom of the convective envelope down to regions where some CNO processing can take place ("*cool bottom processing*"). Modelling circulation with separate downward and upward streams, we found that, to resolve both discrepancies, the base of the extra mixing had to reach a temperature T_P close to that of the H-burning shell, namely, $\Delta \log T \approx 0.17$ from the base of the H-shell for both RGB and AGB. While the envelope composition depends sensitively on T_P, it is insensitive to the speed or geometry of mixing. This indicates that our stream circulation model is generic, so that more sophisticated mixing models with the same T_P would yield similar results. On the AGB, our models predict that stars with low $^{18}O/^{16}O$ can be either S or C stars, but must have low $^{12}C/^{13}C$ (~ 4) and elevated ^{14}N. Cool bottom processing also destroys ^{3}He, so that galactic (D+^{3}He) *decreases* with time; this removes the strongest lower limit on the baryon density Ω_b from Big Bang nucleosynthesis models.

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Detection of Ammonia Emission toward Oxygen-Rich Evolved Stars

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Using the Effelsberg 100-m telescope we have discovered emission in the $(J,K) = (1,1)$ and (2,2) inversion transitions of ammonia (NH_3) toward the circumstellar envelopes of the Mira variable IK Tau and the OH/IR hypergiant IRC+10420. Modeling our spectra, we find that $[NH_3/H_2]$ abundance ratios of a few times 10^{-6} are required to explain the observational results. These values are of the same order as the ammonia abundances previously inferred from infrared absorption measurements toward oxygen-rich evolved stars. The high NH_3 abundances implied by our observations present a challenge to models of circumstellar chemistry, which fall short of reproducing the observed values by several orders of magnitude. We also present high quality spectra of the NH_3 (1,1), (2,2), and (3,3) lines toward the peculiar bipolar nebula OH 231.8+4.2, which is the only oxygen-rich (post-)AGB object with previously detected NH_3 radio emission. Toward this source the (1,1) profile looks strikingly different from the profiles of the (2,2) and (3,3) lines, which resemble each other closely. Similar to many millimeter-wavelength lines from other molecules, the NH_3 (1,1) line shows high-velocity emission. In contrast, the (2,2) and (3,3) lines have narrow line profiles that are quite different from profiles observed in spectra from any other molecule and arise from a warm ($T_{kin} > 50$ K) region close to the central star. The high-velocity material dominating the (1,1) spectrum is emitted from a cooler ($\lesssim 20$ K) more extended region.

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Stellar evolution with mass loss – comparison of numerical and semi-analytical computations.

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We present here results of stellar evolution calculations that include the latest advances in radiative opacities and neutrino cooling, and discuss on the basis of these models how the internal stellar structure responds to mass-loss from the stellar surface. This problem has particular importance for the development of semi-analytical algorithms for efficient calculation of synthetic stellar populations with realistic (and hence complex) mass-loss scenarios. We therefore compare our numerical results with test calculations based on a semi-analytical stellar evolution method developed by us. Although small, but important, differences between results from the two methods are revealed, the evolutionary tracks in the HR-diagram predicted by the two approaches are almost identical.

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Precessing jets and point-symmetric nebulae

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We present a model for the formation of point symmetric nebulae that relies on the existence of a precessing jet interacting with the ISM. Using 3-D numerical simulations we investigate the basic gas-dynamics inherent to the model. Through "synthetic observations" of our simulations we show that episodic precessing jets can reproduce the gross morphological structure of point-symmetric nebulae, i.e. a string of discreet clumps in an 'S'-shaped intensity distribution.

We also find that the bow shocks of the individual jet segments can merge into a single shock structure that envelops the entire complex of segments. The development of this enveloping shock allows the model to embrace nebulae consisting of discrete point-symmetric clumps as well as those bipolar objects that show nonuniform brightness distributions on their opposing lobes that are point-symmetric through the nucleus. By demonstrating that these bipolar PNe can form from the same mechanism which produces the discrete point-symmetric nebulae we can include them in the category of point-symmetric objects thereby increasing their fractional occurence in PNe by 75%.

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He 3-1475 and Its Jets

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We present spectra and high-resolution images taken with HST, the NTT, the VLA, and the MPIA/ESO 2.2m of the emission-line star He 3-1475 which we suggest is a post-AGB star. The star is presumed to be at the origin of a $15''$ long structure containing symmetrically opposing bright knots. The knots have radial velocities of ± 500 km s^{-1} from the center of He 3-1475 to the ends of the jets. HST snapshots show that the core of He 3-1475 is unipolar with a star at the SE end and the nebula fanning out toward the NW. VLA observations show the presence of OH masers, which are positioned parallel to the optical jets. A model is proposed that accounts for all of the observational data. This unusual object may link the OH/IR stars having extreme outflow velocities with highly bipolar planetary nebulae.

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WORKSHOP

Planetary nebulas with WR type nuclei

August 21-25, 1995
Ven, Sweden

Aim : The aim of this workshop is to present problems about those planetary nebulas having WR stars as nuclei, the reason for this and their relation to classical WR stars of high mass.

Organisation : The workshop is organised by Lund Observatory and the local organising committee (LOC) consists of

Eva Jurlander	eva@astro.lu.se
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The scientific organising committee (SOC) consists of

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Participants : The workshop is open to workers within the fields of planetary nebulas and classical WR stars. The number of participants should not exceed 50 persons.

Site : The beautiful island Ven is chosen for the workshop. Ven is situated in Oeresund, the sound between Denmark and Sweden, and belongs since 1658 to Sweden. On Ven, Tycho Brahe (1546-1601), one of the leading figures in pretelescopic astronomy, lived and worked for more than 20 years. He observed then, with great accuracy the positions of the planets, giving rise to the Kepler's laws of planetary motion. Of his castle Uraniborg is nothing left. Parts of the renaissance garden is newly reconstructed and these can, along with the ruins of Stjaerneborg, Brahe's underground observatory, be inspected.

Accommodation : The workshop will be housed in Backafallsbyn, a recreation and conference centre consisting of a number of cottages with conference and restaurant facilities. The cottages can be occupied single or shared of up to 4 persons. The prices are (preliminary figures):

Single occupancy	SEK 4700:-	(USD 630)
2 persons sharing	3500:-	(USD 470)
3 persons sharing	3000:-	(USD 400)
4 persons sharing	2800:-	(USD 370)

A participation fee of SEK 1000 (approx USD 130) will also be asked for, covering the cost for excursions and organisation.

Additional informations : please contact B. STENHOLM at bjorn@astro.lu.se