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Abstract of recently accepted papers

Kinematics of the strange knots and halo of the planetary nebula IC 4593

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Kinematical observations have been made with the Manchester Echelle Spectrometer combined with the San Pedro Mártir telescope of the various features of the strange planetary nebula IC 4593. In particular the outer knots are shown to be inert and extended high-speed flows are found to be emerging from the nebular core. Various models for the whole structure are discussed in the face of these new observations.

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The carbon star IRAS 15194-5115: Circumstellar CO radio and FIR rotational lines

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We have modelled radio and far-infrared rotational lines of ^{12}CO and ^{13}CO obtained from the circumstellar envelope of the infrared-bright carbon star IRAS 15194-5115. Eleven rotational lines between J=1–0 and 21–20 and nine rotational lines between J=1–0 and 22–21 in the ground vibrational states of ^{12}CO and ^{13}CO, respectively, provide the observational constraints. A model of the circumstellar envelope with a constant mass-loss rate ($1\times10^{-5}\,M_{\odot}\,yr^{-1}$) and ^{12}CO/^{13}CO-ratio (5.5) is consistent with our observed FIR and radio data, suggesting that the wind characteristics have not changed significantly over the past few thousand years. Thus, IRAS 15194-5115 appears to be a highly evolved AGB-star, but the carbon star properties combined with the inferred low ^{12}C/^{13}C-ratio make the evolutionary status of this star uncertain. It may have been a J-star for which the ^{12}C/^{13}C-ratio has remained low, or it may be a star of 5 to 8 solar masses, which has recently become a carbon star due to quenching of hot bottom burning. The dust properties or the relative amount of dust in the envelope appear to be different from those in the envelope of the well known carbon star IRC+10 216.

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Preprints can be obtained by contacting ryde@astro.uu.se

The Circumstellar Envelope of π Gru

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CO(J = 2–1) and SiO(J = 5–4) emission has been observed from the molecular envelope around the nearby S star π Gru. The CO line profile differs from the usual parabolic shape seen in uniformly expanding envelopes; it has a Voigt-like profile and two horns. A model for line formation in the envelope shows that a tilted, expanding disk reproduces the observations well. The star also has a fast molecular wind, with a projected outflow speed of at least 70 and perhaps as high as 90 km/s. The fast wind is presumably ejected from the poles of the disk. These observations show that the complex structure seen in many planetary nebulae, including quadrupolar structure and fast winds, may largely evolve from structure formed while the progenitor star is in the last stages of evolution on the AGB.

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IRAS 03313+6058: an AGB star with 30 micron emission

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This paper reports a detection of the 30 micron emission feature from the C–rich Asymptotic Giant Branch (AGB) star IRAS 03313+6058 based on the ISO–SWS observation. Modeling of the spectral energy distribution shows that this emission starts at about 20 micron and possibly extends to the limit (45 micron) of the observation. By assuming MgS as the carrier, the number ratio of Sulfur atom in MgS to Hydrogen atom in total, n(S)/n(H), is 3.0×10^{-6} from model fitting. A comparison of this emission feature is made with other AGB and post–AGB objects.

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Infrared photometry of the inner regions of the Dwarf Irregular Galaxy NGC 3109

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We present the first deep IR/optical colour–magnitude diagrams for a dIr galaxy near the Local Group, NGC 3109. VIJHK photometry was obtained for stars in a 0.8×2.0 kpc^2 inner field of NGC 3109. The infrared photometry reaches 3 magnitudes fainter than previous work, and covers red supergiants as well as stars near the tip of the AGB. The brightest supergiants reach $M_K = -10.8$.

Optical and infrared color–color and color–magnitude diagrams, and the bolometric luminosity function, confirm the presence of AGB stars tracing an intermediate-age stellar population. We construct a $\log L/L_{\odot}$ vs $\log T_{eff}$ diagram of the galaxy and compare the results with the theoretical isochrones of Bertelli et al. (1994, A&AS, 106, 275) for $Z = 0.004$ and $Y = 0.24$. The comparison suggests that most of the stars detected in the IR are 10^9 yr or younger. We compare the infrared color–magnitude diagrams of NGC 3109 with the composite color–magnitude diagrams of LMC clusters and of the outer disk of the Scd galaxy M33. They show similar stellar content in these late-type systems.

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Maser mapping of small scale structure in the circumstellar envelope of S Persei.

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Water and hydroxyl maser emission from the typical red supergiant star S Persei has been mapped using MERLIN. Water maser components are found grouped in clumps which appear to be discrete clouds with a velocity span of $\sim$ 1 km s^{-1} and an angular size of $\sim$ 8 milli-arcsec. This corresponds to a diameter of (2.5 – 3)$\times 10^{12}$ m and is the first measurement of the unbeamed size of maser clouds. By comparing this with the full width half maximum (FWHM) beamed angular size, the beaming angle of the brightest partially saturated masers is $(1.5 \pm 0.8) \times 10^{-3}$ sr. Water maser cloud brightness temperatures are in the range $\sim 10^6$ to $> 10^{12}$ K. The water maser shell has well-defined inner and outer limits of (8 – 26)$\times 10^{12}$ m. The quenching density at the inner rim shows that the water maser clouds are about 30 times denser than the average wind density in this region. This can be explained if 4 – 6 dense dusty clouds (with a filling factor of $\sim 1/70$) are formed close to the photosphere during each stellar pulsation period of 2 – 3 yrs.

The water masers show evidence for significant acceleration of the wind, and this continues with a shallower gradient into the hydroxyl regions at up to 9.3×10^{13} m. These results are consistent with a wind driven by radiation pressure on dust, but the ongoing acceleration implies that the dust surface absorption efficiency increases throughout the maser zones. Dust momentum is more efficiently coupled to the gas in the denser clouds, and the drift velocity is greater in less dense regions consistent with conditions (such as a longer velocity resonance length) required by 1612-MHz masers.

The circumstellar envelope appears to be spherical but irregularly filled. The milli-arcsec resolution at 22 GHz allows the radial distribution of maser brightness to be related to AAVSO light curves. An anomal ously dim region in the centre of the shell corresponds to low-amplitude periods in the 1930s; such behaviour is thought to reduce mass loss and dust formation efficiency.

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High resolution radio observations of HM Sge. II Two decades after outburst.

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HM Sge is a symbiotic binary star which underwent a nova-like outburst in 1975. Its radio emission has been monitored using MERLIN and the VLA, and maps from 1992 to 1997 are presented. Thermal emission within $0''.4$ of the optical peak is elongated north-south and hot spots appear to be moving around an anti-clockwise ellipse. If this is due to motion in an inclined disc, the period is ~ 90 yr. Eyres et al. (1995) predicted that if this is due to Mach shocks in the post-nova wind, proper motions should be seen in expansion. This has not been detected since 1992 so an alternative model is adopted, based on Eyres et al. (1995) and Kenny (1997), of colliding winds in a binary system following the nova-like outburst. The emission peaks appear to be co-rotating with the binary orbit as the ionisation front and the hot wind from the white dwarf interact with the Mira wind. The positions of the stars are estimated, at a separation of ~ 25 au. A distance of ~ 1 kpc is most consistent with the observations reported here.

On arcsecond scales the emission is extended east-west consistent with a biconical outflow arising from the collimation of the nova outburst through interaction with the pre-existing cool wind. The presence of non-thermal emission at a separation of ~ 700 milli-arcseconds from the stars is confirmed. This is very unusual at such a distance from low-mass stars and could arise from synchrotron emission in a μT magnetic field. A model for this is developed which shows non-thermal emission is expected to decline within decades as the nova wind decelerates. This could explain the non-detection of non-thermal emission in other symbiotic stars.

MNRAS (in press)

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Mid-infrared spectra of late-type stars: Long-term evolution

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Recent ground-based mid-infrared spectra of 29 late-type stars, most with substantial dust shells, are compared to ground-based spectra of these stars from the 1960s and 1970s and to IRAS-LRS spectra obtained in 1983. The spectra of about half the stars show no detectable changes, implying that their distributions of circumstellar material and associated dust grain properties have changed little over this time interval. However, many of the stars with strong silicate features showed marked changes. In nearly all cases the silicate peak has strengthened with respect to the underlying continuum, although there is one case (VY CMa) in which the silicate feature has almost completely disappeared. This suggests that, in general, an oxygen-rich star experiences long periods of gradual silicate feature strengthening, punctuated by relatively rare periods when the feature weakens. We discuss various mechanisms for producing the changes, favoring the slow evolution of the intrinsic dust properties (i.e., the chemical composition or grain structure). Although most IRAS spectra agree well with ground-based spectra, there are a number of cases where they fall well outside the expected range of uncertainty. In almost all such cases the slopes of the red and blue LRS spectra do not match in their region of overlap.

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Heating and cooling by iron in cool star winds

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Abstract: The role of iron for the energy balance in the extended atmospheres and circumstellar envelopes of cool stars is explored. Based on large non-LTE model atoms for Fe I and Fe II, we study the influence of fine-structure, forbidden, permitted and bound-free transitions on the radiative heating and cooling of the gas under various temperature, density and radiation field conditions. The results are compared to those obtained in LTE and to those calculated when ignoring optical depth effects in the lines. The number of levels in the model atoms necessary to achieve convergence of the results is discussed.

Keywords: radiation mechanisms: thermal – circumstellar matter – hydrodynamics – shock waves – chromospheres – atomic processes

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The Molecular Envelope of the Helix Nebula

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We present a fully sampled map of the Helix nebula in the 1.3 mm CO $J = 2 - 1$ line, made using the Caltech Submillimeter Observatory. The angular resolution is $31''$ and the velocity resolution is 1.5 km s^{-1}. The CO emission is found to extend over a region $\sim 1000'' \times 800''$ and delineates the well-known double ring or "helix" seen in optical images of the ionized gas. Our observations provide the first complete view of the global kinematics of the envelope, and reveal the 3-dimensional structure of the gas. The helix is seen to be an expanding, equatorial ring around the ionized nebula, with arcs extending to higher latitudes and exhibiting remarkable point symmetries about the central star. The molecular gas is fragmented into many small condensations with narrow line widths ($\sim$ 1 km s^{-1}). The close relationship found between the structure of the envelope and the ionized nebula underscores the important role of neutral gas in determining the morphology of planetary nebulae. The point symmetries provide evidence for early shaping of the envelope by bipolar outflows or jets.

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A new generation of dynamic model atmospheres for AGB stars: first results

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Existing time-dependent dynamic model atmospheres for AGB stars suffer from the fact that they are based on grey radiative transfer which is a poor approximation for cool line-blanketed atmospheres. Therefore, frequency-dependent radiative transfer has been included into a well-tried radiation hydrodynamics code to obtain more

realistic models. First results concerning the structure of such non-grey dynamical model atmospheres are presented in this paper. Due to computational reasons, the number of frequencies used in the radiative transfer has to be kept very low, typically around 50, but even with this restriction considerable improvements can be obtained compared to grey models.

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Non-explosive hydrogen and helium burnings: Abundance predictions from the NACRE reaction rate compilation

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The abundances of the isotopes of the elements from C to Al produced by the non-explosive CNO, NeNa and MgAl modes of hydrogen burning, as well as by helium burning, are calculated with the thermonuclear rates recommended by the European compilation of reaction rates for astrophysics (NACRE: details about NACRE may be found at http://astro.ulb.ac.be. This electronic address also offers the possibility of generating interactively tables of reaction rates for networks and temperature grids selected by the user and provides many other data of nuclear astrophysics interest).

The impact of nuclear physics uncertainties on the derived abundances is discussed in the framework of a simple parametric astrophysical model. These calculations have the virtue of being a guide in the selection of the nuclear uncertainties that have to be duly analyzed in detailed model stars, particularly in order to perform meaningful confrontations between predictions and observations of abundances at the surface of, e.g., AGB stars. These calculations are also hoped to help nuclear astrophysicists pinpointing the rate uncertainties that have to be reduced most urgently.

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Mixing and nucleosynthesis in rotating TP-AGB stars

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We present the first evolutionary models of intermediate mass stars up to their thermal pulses which include effects of rotation on the stellar structure as well as rotationally induced mixing of chemical species and angular momentum. We find a significant angular momentum transport from the core to the hydrogen-rich envelope and obtain a white dwarf rotation rate comparable to current observational upper limits of $\leq 50\,km/s$.

Large angular momentum gradients at the bottom of the convective envelope and the tip of the pulse driven convective shell are shown to produce marked chemical mixing between the proton-rich and the ^{12}C-rich layers during the so called third dredge-up. This leads to a subsequent production of ^{13}C which is followed by neutron production through ^{13}C(α, n) in radiative layers in between thermal pulses. Although uncertainties in the

efficiency of rotational mixing processes persist, we conclude that rotation is capable of producing a ^{13}C-rich layer as required for the occurrence of the s-process in TP-AGB stars.

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The Galactic Evolution of Si, Ti and O Isotopic Ratios

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Most meteoritic presolar grains of SiC and corundum condensed around red giant and asymptotic giant branch (AGB) stars prior to the formation of the Solar System. Here we use new and previously published isotopic data of presolar SiC and corundum grains to constrain the galactic chemical evolution (GCE) of Si, Ti, and O isotopic ratios. The ^{1}2C/^{1}3C ratios of the SiC grains limit the amount of He-shell material mixed to the surface of the parent AGB stars during third dredge-up to a few percent. Thus, the linear correlations observed between the SiC Si and Ti isotopic ratios probably reflect the average GCE trends of these elements. Moreover, the close proximity of these trends to the solar isotopic composition indicates that the latter cannot be very unusual for these elements. A χ^2 fit to the SiC isotopic data has allowed us to accurately estimate the relative GCE paths for the Si and Ti isotopes. The fit estimates the nucleosynthetic components of the grains' compositions, the metallicities of their parent stars and the mean GCE paths of the isotopes. For most of the isotopes, our results agree remarkably well with the GCE calculations of Timmes, Woosley and Weaver and Timmes & Clayton after they are corrected to pass through solar. However, the abundances of both ^{30}Si and ^{47}Ti in the fit increase significantly more slowly with metallicity, relative to the other isotopes, than predicted by the corrected GCE model. Conversely, ^{49}Ti increases more rapidly in the fit than predicted. These discrepancies probably reflect errors in the supernova models used to calculate the GCE paths. Our fit also suggests that the typical ISM at solar metallicity is enriched in ^{29}Si and ^{30}Si (by ~8% and ~5%, respectively) relative to solar. The GCE of the O isotopes cannot yet be so well constrained, but the corundum data are most consistent with a GCE path that passes close to solar rather than one that is ^{18}O depleted as suggested by measurements of molecular clouds. The inferred depletion of ^{29}Si and ^{30}Si in the Sun could be explained by the addition or removal of a small amount of supernova material. However, we can probably rule out a supernova explanation for the apparent enrichment of solar O relative to young stars and the local ISM, and ^{18}O relative to molecular clouds.

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Jets, knots and tails in planetary nebulae: NGC 3918, K 1–2 and Wray 17-1

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We analyze optical images and high-resolution, long-slit spectra of three planetary nebulae which possess collimated, low-ionization features.

NGC 3918 is composed of an inner, spindle-shaped shell mildly inclined with respect to the plane of the sky. Departing from the polar regions of this shell, we find a two-sided jet expanding with velocities which increase linearly with distance from 50 to 100 km s^{-1}. The jet is probably coeval with the inner shell (age $\approx 1000 \cdot D$ y, where D is the distance in kpc), suggesting that its formation should be ascribed to the same dynamical processes which also shaped the main nebula, and not to a more recent mass loss episode. We discuss the formation of the aspherical shell and jet in the light of current hydrodynamical and magnetohydrodynamical theories.

K 1-2 is a planetary nebula with a close binary nucleus which shows a collimated string of knots embedded in a diffuse, elliptical shell. The knots expand with a velocity similar to that of the elliptical nebula ($\sim$25 km s^{-1}), except for an extended tail located out of the main nebula, which linearly accelerates up to $\sim$ 45 km s^{-1}. We estimate an inclination on the line of the sight of $\sim 40°$ for the string of knots; once the orientation of the orbit is also determined, this information will allow us to test the prediction of current theories of the occurrence of polar jets from close binary systems.

Wray 17-1 has a complex morphology, showing two pairs of low-ionization structures located in almost perpendicular directions from the central star, and embedded in a large, diffuse nebula. The two pairs show notable similarities and differences, and their origin is very puzzling.

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Jets and the shaping of the giant bipolar envelope of the planetary nebula KjPn 8

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A hydrodynamic model involving cooling gas in the stagnation region of a collimated outflow is proposed for the formation of the giant parsec-scale bipolar envelope that surrounds the planetary nebula KjPn 8. Analytical calculations and numerical simulations are presented to evaluate the model. The envelope is considered to consist mainly of environmental gas swept-up by shocks driven by an episodic, collimated, bipolar outflow. In this model, which we call the "free stagnation knot" mechanism, the swept-up ambient gas located in the stagnation region of the bow-shock cools to produce a high density knot. This knot moves along with the bow-shock. When the central outflow ceases, pressurization of the interior of the envelope stops and its expansion slows down. The stagnation knot, however, has sufficient momentum to propagate freely further along the axis, producing a distinct nose at the end of the lobe. The model is found to successfully reproduce the peculiar shape and global kinematics of the giant bipolar envelope of KjPn 8.

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Apparent-Double SiO Maser Sources

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In the course of an SiO maser survey of galactic disk IRAS sources at 43 GHz, we found two cases of detections of doubly peaked SiO maser sources in the $40''$ half-power beam of the Nobeyama 45-m telescope. The double peaks in the spectra of these sources (IRAS 18019−1822 and 18465−0717) have velocity separations of 73 and 147 km s^{-1}, indicating that each peak comes from a separate source. Infrared imaging observations found pairs of candidate counterparts for each source with angular separations of about $20''$. Combining the observational data, we conclude that these objects are apparent-double SiO sources, which are by chance seen in the same direction. The discovery rate for pairs of SiO maser sources in a single telescope beam is found to be consistent with the surface density of SiO maser sources in the galactic disk. These sources can be used to measure parallaxes and proper motions with VLBI in the future.

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Dynamic model atmospheres of AGB stars II. Synthetic Near Infrared Spectra of Carbon Stars

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We have calculated synthetic opacity sampling spectra for carbon-rich Asymptotic Giant Branch (AGB) stars based on dynamic model atmospheres presented in the first paper of this series. We discuss how different model parameters influence the resulting synthetic spectra and how the spectra vary with phase. The molecules included are: CO, CH, CN, C_2, HCN, C_2H_2 and C_3. We show in which atmospheric layers the different molecules form, in an attempt to understand the qualitatively different variation with pulsation phase exhibited by various spectral features. Almost all features are blends of transitions from more than one molecule, and we therefore identify the most important transitions and molecules that contribute to the main spectral features from 0.5 to 12 μm. Furthermore, we demonstrate the effect on the individual spectral features due to the carbon depletion when dust is formed in the atmosphere.

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Photo-ionization modelling of planetary nebulae II. Galactic bulge nebulae, a comparison with literature results

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We have constructed photo-ionization models of five galactic bulge planetary nebulae using our automatic method which enables a fully self-consistent determination of the physical parameters of a planetary nebula. The models are constrained using the spectrum, the *IRAS* and radio fluxes and the angular diameter of the nebula. We also conducted a literature search for physical parameters determined with classical methods for these nebulae. Comparison of the distance independent physical parameters with published data shows that the stellar temperatures generally are in good agreement and can be considered reliable. The literature data for the electron temperature, electron density and also for the abundances show a large spread, indicating that the use of line diagnostics is not reliable and that the accuracy of these methods needs to be improved. Comparison of the various abundance determinations indicates that the uncertainty in the electron temperature is the main source of uncertainty in the abundance determination. The stellar magnitudes predicted by the photo-ionization models are in good agreement with observed values.

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ISO observations of obscured Asymptotic Giant Branch stars in the Large Magellanic Cloud

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We present ISO photometric and spectroscopic observations of a sample of 57 bright Asymptotic Giant Branch stars and red supergiants in the Large Magellanic Cloud, selected on the basis of IRAS colours indicative of high mass-loss rates. PHOT-P and PHOT-C photometry at 12, 25 and 60 μm and CAM photometry at 12 μm are used in combination with quasi-simultaneous ground-based near-IR photometry to construct colour-colour diagrams for all stars in our sample. PHOT-S and CAM-CVF spectra in the 3 to 14 μm region are presented for

23 stars. From the colour-colour diagrams and the spectra, we establish the chemical types of the dust around 49 stars in this sample. Many stars have carbon-rich dust. The most luminous carbon star in the Magellanic Clouds has also a (minor) oxygen-rich component. OH/IR stars have silicate absorption with emission wings. The unique dataset presented here allows a detailed study of a representative sample of thermal-pulsing AGB stars with well-determined luminosities.

Accepted by Astronomy and Astrophysics Main Journal

Preprints can be obtained by contacting ntrams@astro.estec.esa.nl

Monitoring of LPVs with an automatic telescope I: Five new short period semiregular variables

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We present light curves of five short period variables of spectral type M. They are the first result of our monitoring program of LPVs with an automatic telescope. The stars vary semiregularly on time scales of about 35 days and with small visual amplitude. It is shown that the Fourier analysis is only of limited use for this kind of stars.

We conclude that this type of variability is more common among M giants than previously thought, and we briefly discuss these variables with the shortest periods among the SRVs.

Accepted by Astronomy & Astrophysics *For preprints, contact* lebzelter@astro.univie.ac.at

A highly collimated bipolar outflow in a protoplanetary nebula: *Hubble Space Telescope* imaging of Hen 401

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We have obtained high-resolution wide- and narrow-band images of the bipolar protoplanetary nebula Hen 401 with the Wide-Field & Planetary Camera 2 onboard the *HST*. Two very long (14".5), cylindrical-shaped bipolar outflow lobes are seen in reflected light, each with a length/width ratio of $\approx$7, probably the largest seen in a protoplanetary nebula so far. The lobes are limb-brightened indicating that they are optically-thin to scattering. The central star, resolved for the first time from the surrounding nebulosity, is girdled by an equatorial torus and a bipolar skirt-like structure, both of which are co-axial with the lobes. A faint halo around the lobes marks the presence of an AGB circumstellar envelope. We find Hα emission from photoionized gas in the vicinity of the central star, and tentatively detect two small shock-emitting blobs located along the nebular axis about $\pm$6".2 from the central star. Comparison of the lobe morphology with theoretical models indicates that the highly-collimated lobes of Hen 401 result from the momentum-driven shock interaction of a high-velocity bipolar jet with the circumstellar envelope of the progenitor AGB star.

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Preprints can be obtained by contacting sahai@grandpa.jpl.nasa.gov

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The ISO spectrum of the planetary nebula NGC 6302: I. Observations

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The spectrum of the planetary nebula NGC 6302 is presented, as it was observed by the ISO short-wavelength spectrometer. The IUE spectrum observed at the same position with the same aperture is also presented.

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Preprints can be obtained by contacting douwe@sron.rug.nl *or via WWW on* http://adress/directory.html *or via anonymous ftp on* ftp://adress/directory/publication.tar

The ISO spectrum of the planetary nebula NGC 6302: II. Nebular Abundances

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The ISO spectrum of NGC 6302 is used, in conjunction with the visible and ultraviolet spectrum, to determine the nebular composition. In addition to being considerably more accurate than previous determinations, the abundances of many more elements (and ions) can be found. A discussion of the previous evolution of the central star, in the light of these abundances, is given. A discussion is also given of the composition of the dust.

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Preprints can be obtained by contacting pottasch@astro.rug.nl *or via WWW on* http://adress/directory.html *or via anonymous ftp on* ftp://adress/directory/publication.tar

Announcements

CSENV: A code for the chemistry of CircumStellar ENVelopes

Gary A. Mamon (IAP) & Alfred E. Glassgold (NYU)

CSENV is a code that computes the chemical abundances for a desired set of species as a function of radius in a stationary, non-clumpy, CircumStellar ENVelope. The chemical species can be atoms, molecules, ions, radicals, molecular ions, and/or their specific quantum states. Collisional ionization or excitation can be incorporated through the proper chemical channels. The chemical species interact with one another and can are subject to photo-processes (dissociation of molecules, radicals, and molecular ions as well as ionization of all species). Cosmic ray ionization can be included. Chemical reaction rates are specified with possible activation temperatures and additional power-law dependences. Photo-absorption cross-sections vs. wavelength, with appropriate thresholds, can be specified for each species, while for H2+ a photoabsorption cross-section is provided as a function of wavelength and temperature. The photons originate from both the star and the external interstellar medium. The chemical species are shielded from the photons by circumstellar dust, by other species and by themselves (self-shielding).

URL: http://www.iap.fr/users/gam/csenv.html