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Abstract of recently accepted papers

Shaping of elliptical Planetary Nebulae – The influence of dust-driven winds of AGB stars

C. Reimers[1], *E.A. Dorfi*[1] *and S. Höfner*[1,2]

[1] Institute for Astronomy (IfA), University of Vienna, Türkenschanzstrasse 17, A-1180 Vienna, Austria

[2] Uppsala Astronomical Observatory, Box 515, SE-75120 Uppsala, Sweden

We calculated a model to investigate the shaping of a PN morphological group, i.e. elliptical PNe, in terms of the so-called Interacting Winds Model. The angle-dependent mass loss generated by a dust driven wind due to a slow rotation of the AGB star is an effective way for the shaping of PNe. The matter which is more concentrated in the equatorial region of the star influences the flow of the fast hot wind originating from the central star, resulting in elliptical or weakly bipolar shapes for the corresponding PNe. A wide range of elliptical shapes can be explained by this model. In contrast to previous studies the angle-dependent mass loss on the AGB is not parameterized by an arbitrary formula but is taken from self-consistent dust-driven wind models. Furthermore we discuss the influence of the different inclination of the PNe in the sky, the interaction with an inhomogenous interstellar medium and the possible effect of a magnetic field in or around the old AGB star. Using detailed morphology studies with the Hubble Space Telescope (HST) we discuss possible scenarios to explain the sometimes very complex structures.

Accepted by A&A. *Preprints can be obtained by contacting* reimers@astro.univie.ac.at

A Paradigm Lost: New Theories for Aspherical PNe

Adam Frank [1]

[1] Dept. of Physics and Astronomy, University of Rochester, Rochester, NY 14627-0171

Theoretical Models for the shaping of PNe are reviewed in light of new high resolution images. The new data indicate the purely hydrodynamic interacting stellar winds model can not recover the full variety of shapes and kinematics. New models, some speculative, others more firmly grounded are discussed. In particular, accretion disks and magnetic fields are identified as two of the most promising avenues of future research. Outstanding issues such as jet formation by PNe disks and dynamo activity in P-AGB stars remain to studied. Finally, new simulations of the Egg Nebula are presented as an example of a "paleontological" study designed to recover the history of an individual object.

To appear in Asymmetrical Planetary Nebulae II, ASP Conference Series, J.H. Kastner, N. Soker, & S. Rappaport, eds *Preprints can be obtained by contacting* afrank@pas.rochester.edu *or via WWW on* http://xxx.lanl.gov/abs/astro-ph/9912191

Measuring angular diameters of extended sources

P.A.M. van Hoof

Kapteyn Astronomical Institute, P.O. Box 800, 9700 AV Groningen, The Netherlands

University of Kentucky, Dept. of Physics and Astronomy, 177 CP Building, Lexington, KY 40506–0055, USA

When measuring diameters of partially resolved sources like planetary nebulae, H II regions or galaxies, often a technique called gaussian deconvolution is used. This technique yields a gaussian diameter which subsequently has to be multiplied with a conversion factor to obtain the true angular diameter of the source. This conversion factor is a function of the FWHM of the beam or point spread function and also depends on the intrinsic surface brightness distribution of the source.

In this paper conversion factors are presented for a number of simple geometries: a circular constant surface brightness disk and a spherical constant emissivity shell, using a range of values for the inner radius. Also more realistic geometries are studied, based on a spherically symmetric photo-ionization model of a planetary nebula. This enables a study of optical depth effects, a comparison between images in various emission lines and the use of power law density distributions. It is found that the conversion factor depends quite critically on the intrinsic surface brightness distribution, which is usually unknown. The uncertainty is particularly large if extended regions of low surface brightness are present in the nebula. In such cases the use of gaussian or second moment deconvolution is not recommended.

As an alternative, a new algorithm is presented which allows the determination of the intrinsic FWHM of the source using only the observed surface brightness distribution and the FWHM of the beam. Hence no assumptions concerning the intrinsic surface brightness distribution are needed. Tests show that this implicit deconvolution method works well in realistic conditions, even when the signal-to-noise is low, provided that the beam size is less than roughly 2/3 of the observed FWHM and the beam profile can be approximated by a gaussian. A code implementing this algorithm is available.

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The collision strength of the [Ne V] infrared fine-structure lines

P.A.M. van Hoof[1,2], *D.A. Beintema*[3], *D.A. Verner*[1], *G.J. Ferland*[1]

[1]University of Kentucky, Dept. of Physics and Astronomy, 177 CP Building, Lexington, KY 40506–0055, USA

[2]Canadian Institute for Theoretical Astrophysics, McLennan Labs, 60 St. George Street, Toronto, ON M5S 3H8, Canada

[3]SRON Laboratory for Space Research, P.O. Box 800, 9700 AV Groningen, The Netherlands

The calculation of accurate collision strengths for atomic transitions has been a long standing problem in quantitative spectroscopy. Most modern calculations are based on the R-matrix method and problems pertaining to the use of this method have led to a discussion of the accuracy of these results. More in particular, based on an analysis of the spectra of NGC 3918 and NGC 6302, Clegg et al. (1987) and Oliva et al. (1996) have questioned R-matrix calculations for the infrared [Ne V] fine-structure transitions. Using improved flux measurements for the [Ne V] lines, we show that the conclusion that these collision strengths would be too high, is not correct. The discrepancies found by Clegg et al. (1987) can be explained by the inaccuracy of the [Ne V] 342.6 nm flux they adopted. The discrepancies found by Oliva et al. (1996) can be explained by the inaccuracy of the *LRS* flux for the [Ne V] 14.32 μm line. Based on the data presented in this paper there is *no reason* to assume that there are any problems with the R-matrix calculations for Ne^{4+} of Lennon & Burke (1994). We show that the data are accurate at the 30 % level or better. This confirms the validity of the close coupling method.

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Multiple molecular outflows in AFGL 2688

P. Cox[1], *R. Lucas*[2], *P.J. Huggins*[3], *T. Forveille*[4], *R. Bachiller*[5], *S. Guilloteau*[2], *J.P. Maillard*[6], *A. Omont*[6]

[1]Institut d'Astrophysique Spatiale, Bât. 120, Université de Paris XI, 91405 Orsay, France

[2]IRAM, 300 rue de la Piscine, F-38406 Saint Martin d'Hères Cedex

[3]Physics Department, New York University, 4 Washington Place, New York, NY 10003, USA

[4] Observatoire de Grenoble, B.P. 53X, 38041 Grenoble Cedex, France [5] IGN Observatorio Astronómico Nacional, Apt 1143, 28800 Alcalá de Henares, Spain

[6] Institut d'Astrophysique de Paris, CNRS, 98bis bd. Arago, 75014 Paris, France

We report high resolution ($1.1'' \times 0.9''$) imaging of the proto-planetary nebula AFGL 2688 in the CO (J=2–1) line and the continuum at 230 GHz, using the IRAM interferometer. The observations reveal with unprecedented detail the structure and the kinematics of the gas ejected by the star over the past few hundred years. Two distinct, high-velocity outflow directions are detected emerging from a central core of gas which surrounds the star: one is oriented north-south along the optical axis, the other is oriented east-west, close to the equatorial plane. We resolve the north-south and east-west outflows into a striking series of collimated, bipolar outflows. The tips of the outflows in the east-west direction correspond precisely to H_2 emission peaks seen in recent HST imaging at 2 μm, providing direct evidence for the impact and likely shaping effects of jets on the nearly spherical AGB molecular envelope. These outflows exemplify the mechanism by which point symmetries are imprinted on the structure of planetary nebulae at early stages of their formation.

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ISOGAL Survey of Baade's Windows

I.S. Glass[1] *and D.R. Alves*[2]

[1] South African Astronomical Observatory, PO Box 9, Observatory 7935, South Africa

[2] Space Telescope Science Institute, Baltimore, MD 21218, USA

The Baade's Windows of low obscuration towards the inner parts of the Galactic bulge represent ideal places in which to develop an understanding of the ISOGAL colour-magnitude diagrams. Unlike the case for the solar neighbourhood, their contents are at a uniform distance from the Sun, affected only by the finite thickness of the Bulge.

The objects detected in the ISOGAL survey are found to be late-type M-giants at the red giant tip or on the Asymptotic Giant Branch (AGB). The ISOGAL colour-magnitude diagrams show that mass-loss starts at about M4 and increases towards later types. Many non-Miras have mass-loss rates similar to shorter-period Miras.

The visible counterparts of the ISOGAL sources have been identified in the database of the MACHO gravitational lensing survey. A first report of this work is included here. It is found that nearly all the ISOGAL sources are semi-regular variables (SRVs), which are many times more numerous than Miras. Their stellar luminosities increase with period. Based on a simple interpretation of the photometry, mass-loss rates from about 10^{-9} $M_\odot$ yr^{-1} to 10^{-7} $M_\odot$ yr^{-1} are found for SRVs with periods in excess of $\sim$60 days.

To appear in "ISO Surveys of a Dusty Universe", eds D. Lemke, M. Stickel and K. Wilke, Lecture Notes in Physics Series, Springer-Verlag. *Preprints can be obtained by contacting* isg@saao.ac.za *or via anonymous ftp on canopus.saao.ac.za* /pub/isg/ringberg.ps.gz

O-bearing Molecules in Carbon-rich Proto-Planetary Objects

F. Herpin[1] *and J. Cernicharo*[1]

[1] Depto Física Molecular, I.E.M., C.S.I.C, Serrano 121, E-28006 Madrid, Spain

We present ISO LWS observations of the proto-planetary nebula CRL 618, a star evolving very fast to the planetary nebula stage. In addition to the lines of ^{12}CO, ^{13}CO, HCN and HNC, we report on the detection of H_2O and OH emission together with the fine structure lines of [OI] at 63 and 145 μm. The abundance of the latter three species relative to ^{12}CO are 4 10^{-2}, 8 10^{-4} and 4.5 (approximate value) in the regions where they are produced. We suggest that O-bearing species other than CO are produced in the innermost region of the circumstellar envelope. The UV photons from the central star photodissociate most of the molecular species produced in the AGB phase and allow a chemistry dominated by standard ion-neutral reactions. Not only allow these reactions the formation of O-bearing species, but they also modify the abundances of C-rich molecules like HCN and HNC for which we found an abundance ratio of $\simeq 1$, much lower than in AGB stars. The molecular abundances in the different regions of the circumstellar envelope have been derived from radiative transfer models and our knowledge of its physical structure.

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High-velocity collimated outflows in planetary nebulae: NGC 6337, He 2-186, and K 4-47

Romano L. M. Corradi-1[1], *Denise R. Gonçalves-1*[1], *Eva Villaver-1*[1], *Antonio Mampaso-1*[1], *Mario Perinotto-2*[2], *Hugo E. Schwarz-3*[3], *and Caterina Zanin-4*[4]

[1] Adress-1 Instituto de Astrofísica de Canarias, c. Via Lactea S/N, E–38200 La Laguna, Tenerife, Spain.

[2] Adress-2 Dipartimento di Astronomia e Scienza dello Spazio, Università di Firenze, Largo E. Fermi 5, 50125 Firenze, Italy.

[3] Adress-3 Nordic Optical Telescope, Apartado 474, E–38700 Sta. Cruz de La Palma, Spain.

[4] Adress-4 Institut für Astronomie, Technikerstr. 25, A-6020 Innsbruck, Austria

We have obtained narrow-band images and high-resolution spectra of the planetary nebulae NGC 6337, He 2-186, and K 4-47, with the aim of investigating the relation between their main morphological components and several low-ionization features present in these nebulae.

The data suggest that NGC 6337 is a bipolar PN seen almost pole on, with polar velocities of $\geq$ 200 km/s. The bright inner ring of the nebula is interpreted to be the "equatorial" density enhancement. It contains a number of low-ionization knots and outward tails that we ascribe to dynamical instabilities leading to fragmentation of the ring or transient density enhancements due to the interaction of the ionization front with previous density fluctuations in the ISM. The lobes show a pronounced point-symmetric morphology and two peculiar low-ionization filaments whose nature remains unclear.

The most notable characteristic of He 2-186 is the presence of two high-velocity ($\geq$135 km/s) knots from which an S-shaped lane of emission departs toward the central star.

K 4-47 is composed of a compact core and two high-velocity, low-ionization blobs. We interpret the substantial broadening of line emission from the blobs as a signature of bow shocks, and using the modeling of Hartigan, Raymond, & Hartman (1987), we derive a shock velocity of $\sim$150 km/s and a mild inclination of the outflow on the plane of the sky.

We discuss possible scenarios for the formation of these nebulae and their low-ionization features. In particular, the morphology of K 4-47 hardly fits into any of the usually adopted mass-loss geometries for single AGB stars. Finally, we discuss the possibility that point-symmetric morphologies in the lobes of NGC 6337 and the knots of He 2-186 are the result of precessing outflows from the central stars.

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A 500 km s^{-1} outflow from the young bipolar planetary nebula Mz 3

M.P. Redman, J.A. O'Connor, A.J. Holloway, M. Bryce and J. Meaburn

Jodrell Bank Observatory, Dept of Physics & Astronomy, University of Manchester, Macclesfield, Cheshire SK11 9DL UK

We report the discovery of a pair of hypersonic ($\simeq \pm 500$ km s^{-1}) velocity features located along the bipolar axis of the young planetary nebula Mz 3. The possible physical mechanisms that can produce such extreme outflows are briefly discussed and compared with mechanisms thought to operate in MyCn 18, He 2-111 and KjPn 8 – all of which exhibit equally remarkable hypersonic outflows of differing kinds.

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Atomic Carbon in the Envelopes of Carbon-Rich Post-AGB Stars

G.R. Knapp[1]*, M. Crosas*[2]*, K. Young*[2]*, and Zeljko Ivezic*[1]

[1] Princeton University Observatory, Princeton, NJ 08544, USA

[2] Center for Astrophysics, 60 Garden St., Cambridge, MA 02138, USA

[3] AAVSO, 25 Birch St., Cambridge, MA 02128-1205, USA

[4] National Radio Astronomy Observatory, PO Box 0, 1003 Lopezville Rd., Socorro, NM 87801, USA

Atomic carbon has been detected in the envelopes of three carbon-rich evolved stars: HD 44179 (=AFGL 915, the 'Red Rectangle'); HD 56126; and, tentatively, the carbon star V Hya. This brings to seven the number of evolved star envelopes in which CI has been detected. Upper limits were found for several other stars, including R CrB. CI was not detected in several oxygen rich post asymptotic giant branch (AGB) stars (OH231.8+4.2, for example), although it is detected in their carbon-rich analogues. Two trends are evident in the data. First, circumstellar envelopes with detectable CI are overwhelmingly carbon rich, suggesting that much of the CI is produced by the dissociation of molecules other than CO. Second, the more evolved the envelope away from the AGB, the higher is the CI/CO ratio. The oxygen-rich supergiant star α Ori remains the only oxygen rich star with a wind containing detectable CI. These data suggest an evolutionary sequence for the CI/CO ratio in cool circumstellar envelopes. This ratio is small (a few %) while the star is on the AGB, and the CI is located in the outer envelope and produced by photodissociation. The ratio increases to about 0.5 as the star evolves away from the AGB because of the dissociation of CO and other carbon-bearing molecules by shocks caused by the fast winds which appear at the end of evolution on the AGB. Finally, the ratio becomes $>> 1$ as the central star becomes hot enough to photodissociate CO.

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Shaping Planetary Nebulae: is it different for [WR] stars?

G.Mellema

Stockholm Observatory, SE–133 36 Saltsjöbaden, Sweden

This review discusses the physics of the formation of planetary nebulae around low mass WR stars, or [WR] stars. It especially focuses on the differences which can be expected due to the different character of the fast winds from these [WR] stars. Their fast winds are more massive and are highly H deficient and metal enriched compared to the winds of normal central stars of planetary nebulae. This is expected to lead to faster expansion velocities for the nebulae and a longer momentum-driven phase in the evolution of the wind-driven bubble,

leading to more turbulent nebulae. The observational evidence also shows that the process which produces the [WR] stars is unlikely to influence the onset of aspherical mass loss, something which can be used as a test for models for aspherical mass loss from AGB and post-AGB stars. Finally it is shown that the nebular characteristics rule out a very late He shell flash as the origin of most [WR] stars.

To appear in the proceedings of "Low mass Wolf-Rayet Stars: origin and evolution", eds. L.B.F.M. Waters, A.A. Zijlstra (Astrophysics and Space Science) *Preprints can be obtained by contacting* garrelt@astro.su.se *or via WWW on* http://www.astro.su.se/preprints.html *or via anonymous ftp on* ftp://ftp.astro.su.se/pub/garrelt/preprints/AdamWR.ps.gz

Molecular bullets in the planetary nebula BD+30°3639

R. Bachiller[1], *T. Forveille*[2], *P.J. Huggins*[3], *P. Cox*[4], *and J.P. Maillard*[5]

[1] IGN Observatorio Astronómico Nacional, Apartado 1143, E-28800 Alcalá de Henares, Spain

[2] Observatoire de Grenoble, B.P. 53X, 38041 Grenoble Cedex, France

[3] Physics Department, New York University, 4 Washington Place, New York, NY 10003, USA

[4] Institut d'Astrophysique Spatiale, Université de Paris XI, 91405 Orsay, France

[5] Institut d'Astrophysique de Paris, CNRS, 98bis bd. Arago, 75014 Paris, France

We report high resolution ($1.0'' \times 0.5''$) CO line imaging of the compact planetary nebula BD+30°3639 that reveals a remarkable pair of high-velocity, molecular knots, or "bullets". These bullets are $\sim 1''$ in size, and are symmetrical about the central star in position ($\pm 3''$ at P.A. $\sim 22°$) and in velocity (± 50 km/s). The mass of each bullet is $\geq 7 \times 10^{-4}$ $M_\odot$ and their kinematic age is ~ 500 yr. The high velocity and symmetry of these structures indicate underlying bipolar jets from the central star that interact with the surrounding neutral gas. The unexpected presence of the bullets in BD+30°3639 strengthens the idea that jets are common and play a crucial role in the shaping of planetary nebulae.

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2 to 45 μm Infrared Spectroscopy of Carbon-Rich Proto-Planetary Nebulae

Bruce J. Hrivnak[1], *Kevin Volk*[2], *& Sun Kwok*[2]

[1] Dept. of Physics and Astronomy, Valpariso University, Valparaiso, IN 46383, USA

[2] Dept. of Physics and Astronomy, University of Calgary, Calgary, AB T2N 1N4, Canada

ISO 2-45 μm observations are presented of seven proto-planetary nebulae (PPNs) and two other carbon-rich objects. The unidentified emission features at 21 and 30 μm are detected in six sources, including four new detections of the 30 μm feature. This previously unresolved 30 μm feature is now resolved, and found to consist of a broad feature peaking at 27.2 μm (the "30 μm" feature) and a narrower feature at 25.5 μm (the "26 μm" feature). This new 26 μm feature is detected in eight sources and is particularly strong in IRAS Z02229+6208 and 16594−4656. The UIR emission features at 3.3, 6.2, 7.7, and 11.3 μm, which are commonly observed in planetary nebulae and HII regions, are also seen in these PPNs. However, their strengths relative to the continuum plateaus at 8 and 12 μm are weaker than in planetary nebulae. The 6.9 μm feature, seen almost exclusively in PPNs, is strong. New millimeter CO and HCN observations were made, which support the carbon-rich nature of the objects and yield the expansion velocities of the gaseous envelopes.

The spectral energy distributions of these PPNs were fitted with a radiative-transfer model, taking into account the emission features at 21, 26, and 30 μm. A significant fraction of the total energy output is emitted in these features: as high as 20% in the 30 μm feature and 8% in the 21 μm feature. The fact that so much energy is carried in these features suggests that the material responsible for these features must be made of abundant

elements, and most likely involves carbon. SiS_2 appears to be ruled out as the emitter of the 21 μm feature due to the absence of a predicted companion feature.

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A hydrodynamical study of multiple-shell planetaries. I. NGC 2438

R.L.M. Corradi[1,2], *D. Schönberner*[3], *M. Steffen*[3] *& M. Perinotto*[4]

[1] Isaac Newton Group of Telescopes, Apartado de Correos 321, E–38700 Santa Cruz de la Palma, Canary Islands, Spain

[2] Instituto de Astrofísica de Canarias, c. Via Lactea S/N, E–38200 La Laguna, Tenerife, Spain

[3] Astrophysikalisches Institut Potsdam, D-14482 Potsdam, Germany

[4] Dipartimento di Astronomia e Scienza dello Spazio, Universitá di Firenze, L.go E. Fermi 5, I-50125 Firenze, Italy

We obtained deep imaging and high-resolution spectroscopy of the planetary nebula NGC 2438. In addition to the bright inner rim and the faint halo-like shell already known from previous imagery, our observations also highlight the existence of an even fainter large halo of nearly spherical shape. Analysis of the surface-brightness profiles and the line splitting indicates a clear ionization stratification within the bright rim, with the flow velocities increasing with distance from the central star, reaching 37 km s^{-1}.

We compared the surface-brightness profiles and kinematical data of NGC 2438 with state-of-the-art radiation-hydrodynamics models, and obtained a surprisingly good qualitative agreement. By means of this modelling we show that the faint, halo-like shell has formed by recombination from a once well-developed photoionized shell in response to a fast luminosity drop of the central star. The large, very faint halo is interpreted as being the relic of the now fully ionized AGB wind. Also the velocity/ionization stratification and the thickness of the bright rim are fully consistent with the prediction of the models for such an evolved planetary nebula.

The properties of NGC 2438 can be explained by assuming that the planetary nebula formation started about 45 000 years after a thermal pulse on the AGB, and that the remnant star continued to burn hydrogen in a shell until burning has stopped quite recently.

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