THE AGB NEWSLETTER

An electronic publication dedicated to Asymptotic Giant Branch stars and related phenomena

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Editors: Jacco van Loon and Albert Zijlstra

Editorial

Dear Colleagues,

It is our pleasure to present the 111$^{\rm th}$ issue of the AGB Newsletter. Many contributions continue to discuss the properties of Planetary Nebulae (not only in the recent PN symposium proceedings). Don't miss the paper by Ludmila Kondratyeva presenting temporal changes in the spectra of PNe — real-time evolution?

There is also increasing interest in the interaction between AGB stars and PNe with the ISM — see for instance the two contributions about the bowshock of R Hya and the PhD thesis of Chris Wareing in this issue of the Newsletter.

Let's hope that the "Why Galaxies Care About AGB Stars" conference in Vienna next week will help us to better understand the PN-progenitors, as well as the impact that AGB stars have on the galaxies which they inhabit.

The next issue will be distributed on the 1$^{\rm st}$ of September; the deadline for contributions is the 31$^{\rm st}$ of August.

Editorially Yours,
Jacco van Loon and Albert Zijlstra

Food for Thought

This month's thought-provoking statement is:

AGB stars play an important rôle in shaping the small scale structure of the interstellar medium

Reactions to this statement or suggestions for next month's statement can be e-mailed to agbnews@astro.keele.ac.uk (please state whether you wish to remain anonymous)

The tails in the Helix Nebula NGC 7293

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We have examined a stream-source model for the production of the cometary tails observed in the Helix Nebula NGC 7293 in which a transonic or moderately supersonic stream of ionized gas overruns a source of ionized gas. Hydrodynamic calculations reveal velocity structures which are in good agreement with the observational data on tail velocities and are consistent with observations of the nebular structure. The results also are indicative of a stellar atmosphere origin for the cometary globules. Tail remnants persist for timescales long enough for their identification with faint striations visible in the nebula gas to be plausible.

Accepted for publication in A&A

Available from astro-ph/0607008

The oxygen abundance calibrations and N/O abundance ratios of ∼40,000 SDSS star-forming galaxies

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Using a large sample of 38,478 star-forming galaxies selected from the Second Data Release of the Sloan Digital Sky Survey database (SDSS-DR2), we derive analytical calibrations for oxygen abundances from several metallicity-sensitive emission-line ratios: [N II]/Hα, [O III]/[N II], [N II]/[O II], [N II]/[S II], [S II]/Hα, and [O III]/Hβ. This consistent set of strong-line oxygen abundance calibrations will be useful for future abundance studies. Among these calibrations, [N II]/[O II] is the best for metal-rich galaxies due to its independence on ionization parameter and low scatter. Dust extinction must be considered properly at first. These calibrations are more suitable for metal-rich galaxies ($8.4 < 12+\log(O/H) < 9.3$), and for the nuclear regions of galaxies. The observed relations are consistent with those expected from the photoionization models of Kewley & Dopita (2002). However, most of the observational data spread in a range of ionization parameter q from 1×10^7 to 8×10^7 cm s^{-1}, corresponding to $\log U = -3.5$ to -2.5, narrower than that suggested by the models. We also estimate the (N/O) abundance ratios of this large sample of galaxies, and these are consistent with the combination of a "primary" and a dominant "secondary" components of nitrogen.

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Available from astro-ph/0607074

On the CO Near-IR Band and the Line Splitting Phenomenon in the Yellow Hypergiant ρ Cassiopeiae

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We report on multi-epoch optical and near-infrared spectroscopy around the first overtone ro-vibrational band of CO in the pulsating yellow hypergiant ρ Cas, one of the most massive stars in the Galaxy and a candidate SN II progenitor. We argue that the double cores of the CO absorption lines, that have previously been attributed to separate circumstellar shells expelled during its recurrent outbursts, result in fact from a superposition of a wide absorption line and a narrow central emission line. The CO line doubling returns over subsequent pulsation cycles, where the superposed line emission assumes its largest intensity near phases of maximum light. We find that the morphology and behavior of the CO band closely resemble the remarkable "line-splitting phenomenon" also observed in optical low-excitation atomic lines. Based on radiative transport calculations we present a simplified model of the near-IR CO emission emerging from cooler atmospheric layers in the immediate vicinity of the photosphere. We speculate that the kinetic temperature minimum in our model results from a periodical pulsation-driven shock wave. We further discuss a number of alternative explanations for the origin of the ubiquitous emission line spectrum, possibly due to a quasi-chromosphere or a steady shock wave at the interface of a fast expanding wind and the ISM. We present a number of interesting spectroscopic similarities between ρ Cas and other types of cool variable supergiants such as the RV Tau and R CrB stars. We further propose a possibly common mechanism for the enigmatic outburst behavior of these luminous pulsating cool stars.

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First Surface-resolved Results with the IOTA Imaging Interferometer: Detection of Asymmetries in AGB stars

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We have measured non-zero closure phases for about 29% of our sample of 56 nearby Asymptotic Giant Branch (AGB) stars, using the 3-telescope Infrared Optical Telescope Array (IOTA) interferometer at near-infrared wavelengths (H-band) and with angular resolutions in the range 5–10 milliarcseconds. These non-zero closure phases can only be generated by asymmetric brightness distributions of the target stars or their surroundings. We discuss how these results were obtained, and how they might be interpreted in terms of structures on or near the target stars. We also report measured angular sizes and hypothesize that most Mira stars would show detectable asymmetry if observed with adequate angular resolution.

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Available from astro-ph/0607156

Suzaku Reveals Helium-burning Products in the X-ray Emitting Planetary Nebula BD +30° 3639

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BD +30° 3639, the brightest planetary nebula at X-ray energies, was observed with *Suzaku*, an X-ray observatory launched on 2005 July 10. Using the X-ray Imaging Spectrometer, the K-lines from C VI, O VII, and O VIII were resolved for the first time, and C/O, N/O, and Ne/O abundance ratios determined. The C/O and Ne/O abundance ratios exceed the solar value by a factor of at least 30 and 5, respectively. These results indicate that the X-rays are emitted mainly by helium shell-burning products.

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A search for spectral variations of planetary nebulae and related objects

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The results of long-term spectral observations were used to search for changes in planetary nebulae and emission-line stars. Significant increase of excitation degree is found in two objects: M1-6 and M1-11.

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Detection of a Far-Infrared Bow-Shock Nebula Around R Hya: the First MIRIAD Results

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We present the first results of the MIRIAD (MIPS [Multiband Imaging Photometer for Spitzer] Infra-Red Imaging of AGB [asymptotic giant branch] Dustshells) project using the Spitzer Space Telescope. The primary aim of the project is to probe the material distribution in the extended circumstellar envelopes (CSE) of evolved stars and recover the fossil record of their mass loss history. Hence, we must map the whole of the CSEs plus the surrounding sky for background subtraction, while avoiding the central star that is brighter than the detector saturation limit. With our unique mapping strategy, we have achieved better than one MJy sr^{-1} sensitivity in three hours of integration and successfully detected a faint (< 5 MJy sr $^{-1}$), extended ($\sim 400''$) far-infrared nebula around the AGB star R Hya. Based on the parabolic structure of the nebula, the direction of the space motion of the star with respect to the nebula shape, and the presence of extended Hα emission co-spatial to the nebula, we suggest that the detected far-IR nebula is due to a bow shock at the interface of the interstellar medium and the AGB wind of this moving star. This is the first detection of the stellar-wind bow-shock interaction for an AGB star and exemplifies the potential of Spitzer as a tool to examine the detailed structure of extended far-IR nebulae around bright central sources.

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A close look into the carbon disk at the core of the planetary nebula CPD-568032

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We present high spatial resolution observations of the dusty core of the Planetary Nebula with Wolf-Rayet central star CPD-568032. These observations were taken with the mid-infrared interferometer VLTI/MIDI in imaging mode providing a typical 300 mas resolution and in interferometric mode using UT2-UT3 47m baseline providing a typical spatial resolution of 20 mas. The visible HST images exhibit a complex multilobal geometry dominated by faint lobes. The farthest structures are located at $7''$ from the star. The mid-IR environment of CPD-568032 is dominated by a

compact source, barely resolved by a single UT telescope in a 8.7 μm filter. The infrared core is almost fully resolved with the three 40-45m projected baselines ranging from -5 to 51 degree but smooth oscillating fringes at low level have been detected in spectrally dispersed visibilities. This clear signal is interpreted in terms of a ring structure which would define the bright inner rim of the equatorial disk. Geometric models allowed us to derive the main geometrical parameters of the disk. For instance, a reasonably good fit is reached with an achromatic and elliptical truncated Gaussian with a radius of 97 ± 11 AU, an inclination of $28 \pm 7^\circ$ and a PA for the major axis at $345 \pm 7^\circ$. Furthermore, we performed some radiative transfer modeling aimed at further constraining the geometry and mass content of the disk, by taking into account the MIDI dispersed visibilities, spectra, and the large aperture SED of the source. These models show that the disk is mostly optically thin in the N band and highly flared.

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No Expanding Fireball: Resolving the Recurrent Nova RS Ophiuchi with Infrared Interferometry

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Following the recent outburst of the recurrent nova RS Oph on 2006 Feb 12, we measured its near-infrared size using the IOTA, Keck, and PTI Interferometers at multiple epochs. The characteristic size of $\sim$3 milliarcseconds hardly changed over the first 60 days of the outburst, ruling out currently-popular models whereby the near-infrared emission arises from hot gas in the expanding shock. The emission was also found to be significantly asymmetric, evidenced by non-zero closure phases detected by IOTA. The physical interpretation of these data depend strongly on the adopted distance to RS Oph. Our data can be interpreted as the first direct detection of the underlying RS Oph binary, lending support to the recent "reborn red giant" models of Hachisu & Kato. However, this result hinges on an RS Oph distance of $\lesssim$540 pc, in strong disagreement with the widely-adopted distance of $\sim$1.6 kpc. At the farther distance, our observations imply instead the existence of a non-expanding, dense and ionized circumbinary gaseous disk or reservoir responsible for the bulk of the near-infrared emission. Longer-baseline infrared interferometry is uniquely suited to distinguish between these models and to ultimately determine the distance, binary orbit, and component masses for RS Oph, one of the closest-known (candidate) SNIa progenitor systems.

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Available from astro-ph/0607399

Infrared Observations of The Helix Planetary Nebula

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We have mapped the Helix (NGC 7293) planetary nebula (PN) with the IRAC instrument on the Spitzer Space Telescope. The Helix is one of the closest bright PN, and therefore provides an opportunity to resolve the small-scale structure in the nebula. The emission from this PN in the 5.8 and 8 μm IRAC bands is dominated by the pure rotational lines of molecular hydrogen, with a smaller contribution from forbidden line emission such as [Ar III] in the ionized region. The IRAC images resolve the "cometary knots" which have been previously studied in this PN. The "tails" of the knots and the radial rays extending into the outer regions of the PN are seen in emission in the IRAC bands. IRS spectra on the main ring and the emission in the IRAC bands are consistent with shock-excited H_2 models, with a small ($\sim$10%) component from photodissociation regions. In the Northeast Arc, the H_2 emission is located in a shell outside of the Hα emission.

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Available from astro-ph/0607541
and from http://cfa-www.harvard.edu/irac/publications/2006refereed/jhora_helix.pdf (hi-res version)

Planetary Nebula Abundances and Morphology: Probing the Chemical Evolution of the Milky

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This paper presents a homogeneous study of abundances in a sample of 79 northern galactic planetary nebulae whose morphological classes have been uniformly determined. Ionic abundances and plasma diagnostics were derived from selected optical line strengths in the literature, and elemental abundances were estimated with the Ionization Correction Factor developed by Kingsbourgh & Barlow (1994). We compare the elemental abundances to the final yields obtained from stellar evolution models of low- and intermediate-mass stars, and we confirm that most Bipolar planetary nebulae have high nitrogen and helium abundance, and are the likely progeny of stars with main-sequence mass larger than 3 $M_\odot$. We derive $<$ Ne/O $>$=0.27, and discuss the implication of such a high ratio in connection with the solar neon abundance. We determine the galactic gradients of oxygen and neon, and found $\Delta \log(\mathrm{O/H})/\Delta R = -0.01$ dex kpc^{-1} and $\Delta \log(\mathrm{Ne/H})/\ \Delta R = -0.01$ dex kpc^{-1}. These flat PN gradients do not reconcile with galactic metallicity gradients flattening with time.

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Available from astro-ph/0607480
and from http://www.noao.edu/noao/staff/letizia/

Broad Hα wings from the optically thin stellar wind of the hot components in symbiotic binaries

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Aims. To model broad Hα wings observed in symbiotic binaries by an optically thin, bipolar stellar wind from their hot components as an alternative to that considering the Raman scattering of Lyη photons on atomic hydrogen.

Methods. Profile-fitting analysis. Comparison of the observed broad Hα wings and their luminosity with those predicted by the model. Results. Synthetic Hα profiles fit excellently the observed wings for $|\Delta v| \gtrsim 200\,\mathrm{km/s}$ in our sample of 10 symbiotic stars during the quiescent as well as active phases. The wing profile formed in the stellar wind can be approximated by a function $f(\Delta v) \propto \Delta v^{-2}$, which is of the same type as that arising from the Raman scattering. Therefore it is not possible to distinguish between these two processes only by modeling the line profile. Some observational characteristics of the Hα-emission, its relationship with the emission measure of the symbiotic nebula and a steep radio spectrum at 1.4 – 15 GHz suggest the ionized stellar wind from the hot component to be the dominant source contributing to the Hα wings during active phases. The model corresponding mass-loss rates from the hot components are of a few $\times 10^{-8}$ $M_\odot$/yr and of a few $\times(10^{-7} - 10^{-6})$ $M_\odot$/yr during quiescent and active phases, respectively.

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Available from astro-ph/0607466

Detached shells as tracers of AGB-ISM bow shocks

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New Spitzer imaging observations have revealed the structure around the Mira variable star R Hya to be a one-sided parabolic arc 100 arcsec to the West stretching from North to South. We successfully model R Hya and its surroundings in terms of an interaction of the stellar wind from an asymptotic giant branch (AGB) star with the interstellar medium (ISM) the star moves through. Our three-dimensional hydrodynamic simulation reproduces the structure as a bow shock into the oncoming ISM. We propose this as another explanation of detached shells around such stars which should be considered alongside current theories of internal origin. The simulation predicts the existence of a tail of ram-pressure-stripped AGB material stretching downstream. Indications for such a tail behind R Hya are seen in IRAS maps.

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Available from astro-ph/0607500

XMM-Newton Observations of the Bipolar Planetary Nebulae NGC 2346 and NGC 7026

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We have obtained X-ray observations of the bipolar planetary nebulae (PNe) NGC 2346 and NGC 7026 with *XMM-Newton*. These observations detected diffuse X-ray emission from NGC 7026 but not from NGC 2346. The X-ray emission from NGC 7026 appears to be confined within the bipolar lobes of the PN and has spectral properties suggesting a thermal plasma emitting at a temperature of $1.1^{+0.5}_{-0.2} \times 10^6$ K. The X-ray spectrum of NGC 7026 is modeled using nebular and stellar abundances to assess whether a significant amount of nebular material has been mixed into the shocked-wind, but the results of this comparison are not conclusive owing to the small number of counts detected. Observations of bipolar PNe indicate that diffuse X-ray emission is much less likely detected in open-lobed nebulae than closed-lobed nebulae, possibly because open-lobed nebulae do not have strong fast winds or are unable to retain hot gas.

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Available from astro-ph/0607519

The Hydrogen Burning Turn-off of RS Ophiuchi 2006

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We report a coordinated multi-band photometry of the RS Oph 2006 outburst and highlight the emission line free y-band photometry that shows a mid-plateau phase at $y \sim 10.2$ mag from day 40 to day 75 after the discovery followed by a sharp drop of the final decline. Such mid-plateau phases are observed in other two recurrent novae, U Sco and CI Aql, and are interpreted as a bright disk irradiated by the white dwarf. We have calculated theoretical light curves based on the optically thick wind theory and have reproduced the observed light curves including the mid-plateau phase and the final sharp decline. This final decline is identified with the end of steady hydrogen shell-burning, which turned out the day $\sim$80. This turnoff date is consistent with the end of supersoft X-ray phase observed with Swift. Our model suggests a white dwarf mass of 1.35 ± 0.01 $M_\odot$, which indicates that RS Oph is a progenitor of Type Ia supernovae.

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Conference Papers

Short-lived isotopes and ^{23}Na production in low mass AGB Stars

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We discuss the synthesis of some short-lived isotopes and of ^{23}Na in thermally pulsing AGB stars with initial mass of 2 $M_\odot$ and two different metallicities ($Z = 1.5 \times 10^{-2}$, corresponding to the metal amount in the Sun, and $Z = 1 \times 10^{-4}$), representative of disk and halo stars, respectively. The different nucleosynthesis channels are illustrated in some details. As previously found, the ^{13}C formed after each third dredge up episode is usually completely consumed by alpha captures before the onset of the subsequent thermal pulse, releasing neutrons. This is the most efficient neutron source in low mass AGB stars, and the resulting s-process nucleosynthesis is at the origin of the solar main component. However, in the solar metallicity model, we find that the temperature of the first formed ^{13}C pocket remains too low during the interpulse and the ^{13}C is not completely burnt, being partially engulfed in the convective zone generated by the following thermal pulse. Due to the rapid convective mixing in this zone, the ^{13}C is exposed to a larger temperature and a nucleosynthesis characterized by a relatively high neutron density develops. The main effect is the strong enhancement of isotopes located beyond some critical branching in the neutron-capture path, like ^{60}Fe, otherwise only marginally produced during a standard s-process nucleosynthesis.

Oral contribution, published in VIII Torino Workshop on Nucleosynthesis in AGB stars
Available from astro-ph/0606374

High-resolution X-ray Spectroscopy of BD +30°3639

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We present preliminary results from the first X-ray gratings spectrometer observations of a planetary nebula (PN). We have used the Chandra X-ray Observatory Low Energy Transmission Gratings Spectrometer (LETGS) to observe the bright, diffuse X-ray source within the well-studied BD +30°3639. The LETGS spectrum of BD +30°3639 displays prominent and well-resolved emission lines of H-like C, O, and Ne and He-like O and Ne. Initial modeling indicates a plasma temperature $T_X \sim 2.5 \times 10^6$ K and abundance ratios of C/O $\sim$ 20, N/O $\lesssim$1, Ne/O $\sim$ 4, and Fe/O $\lesssim$0.1. These results suggest that the X-ray-emitting plasma is dominated by the shocked fast wind from the emerging PN core, where this wind gas likely originated from the intershell region of the progenitor asymptotic giant branch star.

Oral contribution, published in IAU Symposium 234, "Planetary Nebulae in Our Galaxy and Beyond"
Available from astro-ph/0607154

The Chemical Composition of Red Giants, AGB Stars and Planetary Nebulae

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The determinations of element abundances in red-giant stars and in particular in AGB stars are reviewed and the resulting abundances are compared with those obtained for planetary nebulae in the Galaxy and in nearby galaxies. The problems, possibilities and implications of such comparisons when estimating yields from low-mass and intermediate-mass stars are illustrated and commented on.

Oral contribution, published in proceedings of IAU Symposium 234, "Planetary Nebulae in Our Galaxy and Beyond," eds. R. Méndez & M. Barlow
Available from astro-ph/0607218

Reaction Rate Uncertainties: NeNa and MgAl in AGB Stars

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We study the effect of uncertainties in the proton-capture reaction rates of the NeNa and MgAl chains on nucleosynthesis due to the operation of hot bottom burning (HBB) in intermediate-mass asymptotic giant branch (AGB) stars. HBB nucleosynthesis is associated with the production of sodium, radioactive ^{26}Al and the heavy magnesium isotopes, and it is possibly responsible for the O, Na, Mg and Al abundance anomalies observed in globular cluster stars.

We model HBB with an analytic code based on full stellar evolution models so we can quickly cover a large parameter space. The reaction rates are varied first individually, then all together. This creates a knock-on effect, where an increase of one reaction rate affects production of an isotope further down the reaction chain. We find the yields of ^{22}Ne, ^{23}Na and ^{26}Al to be the most susceptible to current nuclear reaction rate uncertainties.

Oral contribution, published in NIC-IX, International Symposium on Nuclear Astrophysics — Nuclei in the Cosmos — IX, CERN, Geneva, Switzerland, 25-30 June, 2006
Available from astro-ph/0607536
and from http://www.astro.uu.nl/∼izzard/papers_and_talks.html

Thesis

Hydrodynamical modelling of planetary nebulae and their interaction with the interstellar medium

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In this thesis, a three-dimensional Computational Fluid Dynamics (CFD) program has been described, made parallel, tested and applied to astrophysical problems. The program, named CUBEMPI, was made parallel using the Message-Passing Interface (MPI) library and examined via simple efficiency tests and more complex performance profilers within the Multi-Processing Environment (MPE) library of MPI.

CUBEMPI was tested with various hydrodynamical problems. CUBEMPI successfully completed all tests and its performance was compared with that of several other CFD schemes. Comparing CUBEMPI with these other schemes, no one scheme performed consistently better than any of the others. CUBEMPI efficiently computes accurate solutions to the Euler equations and thus can be used to simulate fluid flow. CUBEMPI has been shown to be particularly capable of simulating shocks in astrophysical conditions and so was used to consider planetary nebulae (PNe) and their interaction with the interstellar medium (ISM).

Previous modelling of PNe moving through the ISM has been performed in two dimensions (2D) following a detailed evolutionary track of the PN-forming star moving at a low speed. Here CUBEMPI has been used to simulate the interaction in three dimensions (3D) with a range of proper motions using a generic simple "triple-wind" model for the formation of PNe. This modelling has considered the asymptotic giant branch (AGB) and post-AGB stages of evolution and led to the conclusion that to understand the shape of a nebula inferred to be moving through the ISM, the AGB evolution must be considered as well as the post-AGB evolution as it has a strong shaping effect on the nebula. Signs of PN-ISM interaction are found not to be confined to ancient or extreme nebulae. In this thesis, simulated younger nebulae moving at low speeds show one-sided brightening and displacement of the central star from the geometric centre of the nebula. At higher speeds the nebulae are strongly affected and eventually no longer appear symmetric. The effect of ISM shaping on nebulae has been quantitatively shown in this thesis to be an explanation for the missing mass problem in PNe; much of the AGB material is swept downstream of the nebula.

New observations of the crescent shaped nebula Sh 2-188 have been compared to the PN-ISM simulations and the nebula has been understood in terms of a PN moving at 125 km/s. A proper motion study of the nebula has found it to be moving at 30 ± 10 mas yr^{-1} in the direction of the bright crescent. The combination of these values has led to an estimate of the distance $D = 850^{+500}_{-420}$ pc, diameter $d \sim 2.5$ pc and age $t_{\rm PN} = 22,500 \pm 2,500$ years. The triple-wind model explains the geometric displacement of the central star and the simulation estimates $\sim$2/3 of the mass expected in the region of the star has been swept downstream. The nebula surrounding the classical nova GK Persei has also been investigated in terms of the triple-wind model using an asymmetric AGB wind. The model has produced a bipolar nebula of the shape observed around GK Per and high density equatorial regions which could account for the brightened emission in the southwest of the nova. Finally, improvements of CUBEMPI and the models are suggested.

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