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 112$^{\rm th}$ issue of the AGB Newsletter. It was great to see many of you at the Vienna conference on the rôle of AGB stars in the evolution of galaxies. One week seemed much too short to fully explore this connection, but the meeting has certainly stimulated a lot of thought and discussion, and we eagerly await the fruits of the research which it has seeded.

This issue of the AGB Newsletter features some of the first results of revolutionary surveys with the Spitzer Space Telescope of the Small and Large Magellanic Clouds (Bolatto et al. and Blum et al., respectively) as well as a galactic synthesis of carbon stars (Guandalini et al.). Planetary Nebulae remain popular objects of research; not only do they represent a key stage in the final evolutionary stages of stars that cover a wide range in age, but they can also be used to directly measure the products of nucleosynthesis in, and the chemical enrichment due to these stars. Don't miss the PhD thesis by Nicholas Sterling on related research.

The next issue will be distributed on the 1$^{\rm st}$ of October; the deadline for contributions is the 30$^{\rm th}$ of September.

Editorially Yours,
Jacco van Loon and Albert Zijlstra

Food for Thought

This month's thought-provoking statement is:

Why do galaxies care about AGB stars?

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)

Refereed Journal Papers

High-J v=0 SiS Maser Emission in IRC +10216: A New Case of Infrared Overlaps

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We report on the first detection of maser emission in the J=11-10, J=14-13, and J=15-14 transitions of the v=0 vibrational state of SiS toward the carbon-rich star IRC +10216. These masers seem to be produced in the very inhomogeneous region between the star and the inner dust formation zone, located at $\simeq$(5-7)$R_\star$, with expansion velocities below 10 km s^{-1}. We interpret the pumping mechanism as being due to overlaps between v=1-0 rovibrational lines of SiS and mid-IR lines of C_2H_2, HCN, and their ^{13}C isotopologues. The large number of overlaps found suggest the existence of strong masers for high-J v=0 and v=1 SiS transitions, located in the submillimeter range. In addition, it could be possible to find several rotational lines of the SiS isotopologues displaying maser emission.

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The "Principes de Asturias" nebula: a new quadrupolar planetary nebula from the IPHAS survey

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The Isaac Newton Telescope Photometric H-alpha Survey (IPHAS) is currently mapping the Northern Galactic plane reaching to $r' = 20$ mag with typically $1''$ resolution. Hundreds of Planetary Nebulae (PNe), both point-like and resolved, are expected to be discovered. We report on the discovery of the first new PN from this survey: it is an unusual object located at a large galactocentric distance and has a very low oxygen abundance. The nebula shows an intricate morphology: there is an inner ring surrounding the central star, bright inner lobes with an enhanced waist, and very faint lobular extensions reaching up to more than $100''$. We classify it as a quadrupolar PN, a rather unusual class of planetary showing two pairs of misaligned lobes. From long-slit spectroscopy we derive T_e[N II]$= 12800 \pm 1000$ K, $N_e = 390 \pm 40$ cm^{-3}, and chemical abundances typical of Peimbert's Type I nebulae (He/H=0.13, N/O=1.8) with an oxygen abundance of $12 + \log(O/H) = 8.17 \pm 0.15$. A kinematic distance of 7.0 kpc is derived, implying an unusually large size of > 4 pc for the nebula. The photometry of the central star indicates the presence of a relatively cool companion. This, and the evidence for a dense circumstellar disk and quadrupolar morphology, all of which are rare among PNe, support the hypothesis that this morphology is related to binary interaction.

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Available from astro-ph/0608108

Planetary nebulae abundances and stellar evolution

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A summary is given of planetary nebulae abundances from ISO measurements. It is shown that these nebulae show abundance gradients (with galactocentric distance), which in the case of neon, argon, sulfur and oxygen (with four exceptions) are the same as H II regions and early type star abundance gradients. The abundance of these elements predicted from these gradients at the distance of the Sun from the center are exactly the solar abundance. Sulfur is the exception to this; the reason for this is discussed. The higher solar neon abundance is confirmed; this is discussed in terms of the results of helioseismology. Evidence is presented for oxygen destruction via ON cycling having occurred in the progenitors of four planetary nebulae with bilobal structure. These progenitor stars had a high mass, probably greater than 5 solar masses. This is deduced from the high values of He/H and N/H found in these nebulae. Formation of nitrogen, helium and carbon are discussed. The high mass progenitors which showed oxygen destruction are shown to have probably destroyed carbon as well. This is probably the result of hot bottom burning.

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Spitzer SAGE survey of the Large Magellanic Cloud II: Evolved Stars and Infrared Color Magnitude Diagrams

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Color-magnitude diagrams (CMDs) are presented for the Spitzer SAGE (Surveying the Agents of a Galaxy's Evolution) survey of the Large Magellanic Cloud (LMC). IRAC and MIPS 24 μm epoch one data are presented. These data represent the deepest, widest mid-infrared CMDs of their kind ever produced in the LMC. Combined with the 2MASS survey, the diagrams are used to delineate the evolved stellar populations in the Large Magellanic Cloud as well as Galactic foreground and extragalactic background populations. Some 32000 evolved stars brighter than the tip of the red giant branch are identified. Of these, approximately 17500 are classified as oxygen-rich, 7000 carbon-rich, and another 1200 as "extreme" asymptotic giant branch (AGB) stars. Brighter members of the latter group have been called "obscured" AGB stars in the literature owing to their dusty circumstellar envelopes. A large number (1200) of luminous oxygen–rich AGB stars/M supergiants are also identified. Finally, there is strong evidence from the 24 μm MIPS channel that previously unexplored, lower luminosity oxygen-rich AGB stars contribute significantly to the mass loss budget of the LMC (1200 such sources are identified).

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Infrared Photometry and Evolution of Mass-Losing AGB Stars. I. Carbon Stars Revisited

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As part of a reanalysis of galactic Asymptotic Giant Branch (AGB) stars at infrared (IR) wavelengths, we discuss a sample (357) of carbon stars for which mass loss rates, near-IR photometry and distance estimates exist. For 252 sources we collected mid-IR fluxes from the MSX (6C) and the ISO-SWS catalogues. Most stars have spectral energy distributions up to 21 μm, and some (1/3) up to 45 μm. This wide wavelength coverage allows us to obtain reliable bolometric magnitudes. The properties of our sample are discussed with emphasis on $\sim$ 70 stars with astrometric distances. We show that mid-IR fluxes are crucial to estimate the magnitude of stars with dusty envelopes. We construct HR diagrams and show that the luminosities agree fairly well with model predictions based on the Schwarzschild's criterion, contrary to what is widely argued in the literature. A problem with the brightness of C stars does not appear to exist. From the relative number of Mira and Semiregular C-variables, we argue that the switch between these classes is unlikely to be connected to thermal pulses. The relevance of the two populations varies with the evolution, with Miras dominating the final stages. We also analyze mass loss rates, which increase for increasing luminosity, but with a spread that probably results from a dependence on a number of parameters (like e.g. different stellar masses and different mechanisms powering stellar winds). Instead, mass loss rates are well monitored by IR colours, especially if extended to 20 μm and beyond, where AGB envelopes behave like black bodies. From these colours the evolutionary status of various classes of C stars is discussed.

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Mythbusting the Carbon Star Dust Condensation Sequences: Anarchist C-Stars

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There have been several investigations of the evolution of the mid-infrared (IR) dust features in carbon star spectra based on IRAS LRS data, but these studies are somewhat contradictory. In order to understand these differences in interpretations and to develop an understanding of the carbon star dust sequence, we have re-examined 26 IRAS LRS spectra of carbon stars that have also been observed spectroscopically by ISO SWS. The low resolution and narrow wavelength coverage of the IRAS LRS data hinder determination of the effect of molecular absorptions in these spectra. This has led to incorrect estimations of the continuum levels in these spectra, which has a huge effect on the continuum-divided and continuum-subtracted spectra used to analyze trends in the shape, strength, and position of the mid-IR features. The higher resolution and broader wavelength coverage of the ISO data allow more accurate fitting of the underlying continuum. We have re-assessed the trends in shape, strength, and position of the $\sim$11 μm silicon carbide (SiC) feature, and the apparent emergence of the $\sim$9 μm feature. We find that there are no correlations between the spectral parameters. We also investigated whether any of these parameters correlate with the strength of the molecular bands; no correlation were found. Moreover, we show that the apparent 9 μm feature is probably an artifact. We discuss the implications of this study, in terms of both a carbon star condensation sequence and the application of this study to the larger IRAS dataset.

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A spectroscopic atlas of post-AGB stars and planetary nebulae selected from the IRAS Point Source Catalogue

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Aims: We study the optical spectral properties of a sample of stars showing far infrared colours similar to those of well-known planetary nebulae. The large majority of them were unidentified sources or poorly known in the literature at the time when this spectroscopic survey started, some 15 years ago.
Methods: We present low-resolution optical spectroscopy, finding charts and improved astrometric coordinates of a sample of 253 IRAS sources.
Results: We have identified 103 sources as post-AGB stars, 21 as "transition sources", and 36 as planetary nebulae, some of them strongly reddened. Among the rest of sources in the sample, we were also able to identify 38 young stellar objects, 5 peculiar stars, and 2 Seyfert galaxies. Up to 49 sources in our spectroscopic sample do not show any optical counterpart, and most of them are suggested to be heavily obscured post-AGB stars, rapidly evolving on their way to becoming planetary nebulae.
Conclusions: An analysis of the galactic distribution of the sources identified as evolved stars in the sample is presented together with a study of the distribution of these stars in the IRAS two-colour diagram. Finally, the spectral type distribution and other properties of the sources identified as post-AGB in this spectroscopic survey are discussed in the framework of stellar evolution.

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The Chemical Evolution of Helium in Globular Clusters: Implications for the Self-Pollution Scenario

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We investigate the suggestion that there are stellar populations in some globular clusters with enhanced helium ($Y \sim$ 0.28 to 0.40) compared to the primordial value. We assume that a previous generation of massive Asymptotic Giant Branch (AGB) stars have polluted the cluster. Two independent sets of AGB yields are used to follow the evolution of helium and CNO using a Salpeter initial mass function (IMF) and two top-heavy IMFs. In no case are we able to produce the postulated large $Y \sim 0.35$ without violating the observational constraint that the CNO content is nearly constant.

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First stars X. The nature of three unevolved Carbon-Enhanced Metal-Poor stars

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From high-resolution VLT/UVES spectra ($R \sim 43,000$), we determine abundances or upper limits for Li, C, N, O, and other important elements, as well as $^{12}C/^{13}C$ isotopic ratio for three Carbon enhanced metal poor stars. All three stars have $-3.30 \leq$ [Fe/H] ≤ -2.85 and moderate to high CNO abundances. CS 22958−042 is one of the most carbon-rich CEMP stars known ([C/Fe] = +3.2), while CS 29528−041 (one of the few N-enhanced metal-poor stars known) is one of the most nitrogen rich ([N/Fe] = +3.0). Oxygen is very high in CS 31080−095 ([O/Fe] = +2.35) and in CS 22958−042 ([O/Fe] = +1.35). All three stars exhibit [Sr/Fe] < 0; Ba is not detected in CS 22958−042 ([Ba/Fe] < -0.53), but it is moderately enhanced ([Ba/Fe] ~ 1) in the other two stars. CS 22958−042 displays one of the largest sodium overabundances yet found in CEMP stars ([Na/Fe] = +2.8). CS 22958−042 has $^{12}C/^{13}C = 9$, similar to most other CEMP stars without enhanced neutron-capture elements, while $^{12}C/^{13}C \leq 40$ in CS 31080−095. CS 31080−095 and CS 29528−041 have A(Li) ~ 1.7, below the Spite Plateau, while Li is not detected in CS 22958−042. CS 22958−042 is a CEMP-no star, but the other two stars are in no known class of CEMP star and thus either constitute a new class or are a link between the CEMP-no and CEMP-s classes, adding complexity to the abundance patterns for CEMP stars. We interpret the abundance patterns in our stars to imply that current models for the presumed AGB binary progenitors lack an extra-mixing process, similar to those apparently operating in RGB stars.

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Structured Red Giant Winds with Magnetized Hot Bubbles and the Corona/Cool Wind Dividing Line

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(Abridged) By performing MHD simulations, we investigate mass loss of intermediate/low-mass main sequence and red giant stars. Alfven waves, which are excited by the photospheric perturbations due to the surface convections, travel outwardly and dissipate by nonlinear processes to accelerate and heat stellar winds. We dynamically treat these processes in open magnetic field regions from the photospheres to 25 stellar radii. When the star evolves to slightly blueward of the dividing line (Linsky & Haisch), the steady hot corona with temperature $\sim 10^6$ K, suddenly disappears. Instead, many hot ($\sim 10^6$ K) and warm ($\gtrsim 10^5$ K) bubbles are formed in cool ($T \lesssim 2 \times 10^4$ K) chromospheric winds because of thermal instability; the RGB star wind is not a steady stream but structured outflow. The densities of the bubbles which are supported by the magnetic pressure can be kept low to reduce the radiative cooling so that the bubbles survive a long time. Even in the stars redward of the dividing line, hot bubbles intermittently exist, which can be sources of UV/X-ray emissions from hybrid stars. Mass loss rates of RGB stars largely vary in time because of many bubbles and blobs; e.g. mass loss rate of a 3 $M_\odot$ star with $\log g = 1.4$ varies from 10^{-10} to 5×10^{-7}

($M_\odot$/yr). The wind velocity also rapidly decreases with the stellar evolution to 10-50 km/s, slower than the surface escape velocity, because the wind is practically accelerated from ∼several stellar radii below which the atmosphere is quasi-static.

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A new interpretation of the remarkable X-ray spectrum of the symbiotic star CH Cyg

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We have reanalysed the ASCA X-ray spectrum of the bright symbiotic star CH Cyg, which exhibits apparently distinct hard and soft X-ray components. Our analysis demonstrates that the soft X-ray emission can be interpreted as scattering of the hard X-ray component in a photo-ionised medium surrounding the white dwarf. This is in contrast to previous analyses in which the soft X-ray emission was fitted separately and assumed to arise independently of the hard X-ray component.
We note the striking similarity between the X-ray spectra of CH Cyg and Seyfert 2 galaxies, which are also believed to exhibit scattering in a photo-ionised medium.

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Variability in red supergiant stars: pulsations, long secondary periods and convection noise

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We study the brightness variations of galactic red supergiant stars using long-term visual light curves collected by the American Association of Variable Star Observers (AAVSO) over the last century. The full sample contains 48 red semiregular or irregular variable stars, with a mean time-span of observations of 61 years. We determine periods and period variability from analyses of power density spectra and time-frequency distributions. We find two significant periods in 18 stars. Most of these periods fall into two distinct groups, ranging from a few hundred to a few thousand days. Theoretical models imply fundamental, first and possibly second overtone mode pulsations for the shorter periods. Periods greater than 1000 days form a parallel period-luminosity relation that is similar to the Long Secondary Periods of the Asymptotic Giant Branch stars. A number of individual power spectra shows a single mode resolved into multiple peaks under a Lorentzian envelope, which we interpret as evidence for stochastic oscillations, presumably caused by the interplay of convection and pulsations. We find a strong 1/f noise component in the power spectra that is remarkably similar in almost all stars of the sample. This behaviour fits the picture of irregular photometric variability caused by large convection cells, analogous to the granulation background seen in the Sun.

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Planetary Nebula Candidates in Extragalactic Young Star Clusters

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During an analysis of optical spectra of 80 young star clusters in several nearby spiral galaxies, [O III] and [N II] emission lines were noted in some cases. Three of these emission line sources are identified as likely planetary nebula (PN) candidates and may represent a rare opportunity to study PNe whose progenitor stars are known to be of intermediate masses. This paper presents and discusses basic properties of the PN candidates and their host clusters. Based on the observed emission line fluxes, the excitation parameters and luminosities of the nebulae are derived. This allows a crude placement of the central stars in two of the objects on the H-R diagram, and their temperatures and luminosities are found to be consistent with post-AGB model tracks for a central star mass of about 0.60 $M_\odot$. Host cluster ages and masses are estimated from broad-band colours and by fitting model SSP spectra to the observed spectra. One of the host clusters has an age of 32-65 Myrs, corresponding to a main sequence turn-off mass of $M(\mathrm{TO}) = 6.6$-9.0 $M_\odot$. For the other cluster the age is 282-407 Myrs, corresponding to $M(\mathrm{TO}) = 3.2$-3.6 $M_\odot$. By estimating the number of stars evolving off the main sequence per year, a total of 6 PNe are expected in our full sample of 80 clusters for a PN lifetime of 10000 years. The factor of two disagreement with the actual observed number may be due, among other things, to uncertainties in PN lifetimes. It is interesting to note that all three PN candidates are associated with clusters which are more diffuse than average. While PNe have previously been found in some old globular clusters, the candidates identified here are among the first identified in young star clusters.

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Population synthesis for symbiotic stars with white dwarf accretors

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We have carried out a detailed study of symbiotic stars with white dwarf accretors by means of a population synthesis code. We estimate the total number of symbiotic stars with white dwarf accretors in the Galaxy as 1,200 – 15,000. This range is compatible with observational estimates. Two crucial physical parameters that define the birthrate and number of symbiotic stars are the efficiency of accretion by white dwarfs (which greatly depends on the separation of components after common envelope stage and stellar wind velocity) and the mass of the hydrogen layer which the white dwarf can accumulate prior to the hydrogen ignition. The theoretical estimate of the Galactic occurrence rate of symbiotic novae ranges from about 1.3 to about 13.5 yr^{-1}, out of which weak symbiotic novae comprise about 0.5 to 6.0 yr^{-1}, depending on the model assumptions. We simulate the distributions of symbiotic stars over orbital periods, masses of components, mass-loss rates of cool components, mass-accretion rates of hot components and luminosity of components. Agreement with observations is reasonable.

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Helium-rich thermonuclear bursts and the distance to the accretion-powered millisecond pulsar SAX J1808.4−3658

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We analysed Rossi X-ray Timing Explorer observations of the accretion-powered 401 Hz pulsar SAX J1808.4−3658, in order to precisely determine the source distance. While the fluences for the five transient outbursts observed from 1996 were constant to within the uncertainties, the outburst interval varied signficantly, so that the time-averaged flux (and accretion rate) decreased by around 40%. By equating the time-averaged X-ray flux with the expected mass transfer rate from gravitational radiation, we derived a lower limit on the distance of 3.4 kpc. Combined with an upper limit from assuming that the four radius-expansion thermonuclear bursts observed during the 2002 October outburst reached at most the Eddington limit for a pure He atmosphere, we found that the probable distance range for the source is 3.4-3.6 kpc. The implied inclination, based on the optical/IR properties of the counterpart, is $i \lesssim 30$ degrees. We compared the properties of the bursts with an ignition model. The time between bursts was long enough for hot CNO burning to significantly deplete the accreted hydrogen, so that ignition occurred in a pure helium layer underlying a stable hydrogen burning shell. This is the first time that this burning regime has been securely observationally identified. The observed energetics of the bursts give a mean hydrogen fraction at ignition of $\langle X \rangle \approx 0.1$, and require that the accreted hydrogen fraction X_0 and the CNO metallicity $Z_{\rm CNO}$ are related by $Z_{\rm CNO} \approx 0.03(X_0/0.7)^2$. We show that in this burning regime, a measurement of the burst recurrence time and energetics allows the local accretion rate onto the star to be determined independently of the accreted composition, giving a new method for estimating the source distance which is in good agreement with our other estimates.

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XMM-Newton high-resolution spectroscopy reveals the chemical evolution of M 87

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We present a study of chemical abundances in the giant elliptical galaxy M 87 using high-resolution spectra obtained with the Reflection Grating Spectrometers during two deep XMM-Newton observations. While we confirm the two-temperature structure of the inter-stellar medium (ISM) in M 87, we also show that a continuous temperature distribution describes the data equally well. The high statistics allows us, for the first time, to determine relatively accurate abundance values also for carbon and nitrogen. The comparison of the abundance ratios of C, N, O, and Fe in the ISM of M 87 with those in the stellar population of our Galaxy shows that the relative contribution of core-collapse supernovae to the enrichment of the ISM in M 87 is significantly less than in the Milky Way and indicates that the enrichment of the ISM by iron through Type Ia supernovae and by carbon and nitrogen is occurring in parallel. This suggests that the main source of carbon and nitrogen in M 87 are the low- and intermediate-mass asymptotic giant branch stars. From the oxygen to iron abundance ratio in the hot gas we estimate that the relative number of core collapse and type Ia supernovae contributing to the enrichment of the ISM in the core of M 87 is ∼60% and ∼40% respectively. The spatial distributions of iron and oxygen are different. While the oxygen abundance distribution is flat the iron abundance peaks in the core and has a gradient throughout the $\sim 4'$ wide field of view of the instrument, suggesting an early enrichment by core-collapse supernovae and a continuous contribution of type Ia supernovae.

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The period-luminosity relation for type II Cepheids in globular clusters

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This paper includes the results of our near-infrared observations for type II Cepheids in globular clusters. The Cepheids may be in pre- or post-AGB phases or even in a blue excursion phase during the AGB. We found a clear period-luminosity relation for them, and discovered that cluster RR Lyr variables also follow the same relation. The period-luminosity relation can be reproduced using the pulsation equation assuming that all the stars have the same mass. These results provide important constraints on the parameters of the variable stars and the related evolutionary phases.

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Bubbles in Planetary Nebulae and clusters of galaxies: precessing jets

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I derive the condition for narrow jets with varying axis, e.g., precessing jets, to inflate more or less spherical (fat) bubbles in planetary nebulae and clusters of galaxies. This work follows a previous work dealing with wide jets, i.e., having a wide opening angle. The expressions derive here are qualitatively and quantitatively similar to the conditions for inflating fat bubbles by non-precessing wide jets. This follows the similar physical cause of inflating fat bubbles, which is that the jet deposits energy inside the bubble. Fat bubbles in planetary nebulae (and similar stellar systems) and in clusters of galaxies, are likely to be formed by wide jets, precessing jets, or other jets whose axis is not constant relative to the medium they expand into.

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HST Images of Magellanic Cloud Planetary Nebulae

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We present images and slitless spectra which were obtained in HST surveys of Planetary Nebulae (PNe) in both the Large and Small Magellanic Clouds, using the Space Telescope Imaging Spectrograph. These new data on 59 PNe (54

in the LMC and five in the SMC) permit us to determine the nebular dimensions and morphology in the monochromatic light of several emission lines: Hα, [N II] 6583 and [O III] 5007, plus others of varying ionization, including [O I], He I, and [S II]. We describe the nebular morphology and related features in detail. This survey, when combined with similar data from our prior HST programs and other archived PN images, brings the total of nebulae imaged with HST to 114 in the LMC and 35 in the SMC. We describe various basic properties for the sample, including sizes, morphologies, densities, and completeness. Trends in [O III] 5007 flux, surface brightness, and electron density with physical radius suggest that many nebulae, particularly those with bipolar morphology, may be optically thick even at large size. Bipolars also show the most extreme values of [N II]/Hα flux ratios, which is a rough indicator N enrichment.

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The distribution of maser stars in the inner Milky Way: the effect of a weak, rotating bar

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We derive the distribution of maser stars in the inner Milky Way (MW) based on an analysis of lV-diagrams (lVd) for two samples of maser stars: 771 OH/IR stars and 363 SiO-maser stars. They are all close to the plane of the MW and have long. from -45 to $+45°$. The two lVds are compared and found to be very similar. They also compare well with the lVd of interstellar CO, but there are significant differences in detail between the stellar lVds and that of the ISM. Based on the qualitative discussion we divide the lVds into seven areas. In each area we compare the number of stars observed with those predicted by an assumed set of orbits in a galactic potential. This potential is axially symmetric but a weak rotating bar has been added. We conclude that the maser stars move on almost circular orbits outside of about 3.5 kpc, but that the orbits become more and more elongated when one goes deep inside our MW. We find a strong effect of the Corotation (CR) resonance (res) at 3.3 kpc, we see a small but noticeable effect of the Outer Lindblad res at 5 kpc and no effect of the Inner Lindblad res at $r = 0.8$ kpc. We find a set of 6 groups of orbits that together predict counts in agreement with the counts of stars observed. We then calculate the trajectory of each orbit and so find the distribution of the maser stars in the plane of the MWG. This distribution has two new (but not unexpected) features. The first is a bar-like distribution within 2 kpc from the GC outlined. These orbits explain the high-vel stars near $l = 0°$ in the forbidden and the permitted quadrants. The second feature are two "croissant"-like voids in the distribution close to the CR radius (3.3 kpc), which are the consequence of the presence of the CR res. We find excellent agreement with an earlier reconstruction by Sevenster (1999).

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A Search for Nitrogen-Enhanced Metal-Poor Stars

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Theoretical models of very metal-poor intermediate-mass Asymptotic Giant Branch (AGB) stars predict a large overabundance of primary nitrogen. The very metal-poor, carbon-enhanced, s-process-rich stars, which are thought to be the polluted companions of now-extinct AGB stars, provide direct tests of the predictions of these models. Recent studies of the carbon and nitrogen abundances in metal-poor stars have focused on the most carbon-rich stars, leading to a potential selection bias against stars that have been polluted by AGB stars that produced large amounts

of nitrogen, and hence have small [C/N] ratios. We call these stars Nitrogen-Enhanced Metal-Poor (NEMP) stars, and define them as having [N/Fe] $> +0.5$ and [C/N] < -0.5. In this paper, we report on the [C/N] abundances of a sample of 21 carbon-enhanced stars, all but three of which have [C/Fe] $< +2.0$. If NEMP stars were made as easily as Carbon-Enhanced Metal-Poor (CEMP) stars, then we expected to find between two and seven NEMP stars. Instead, we found no NEMP stars in our sample. Therefore, this observational bias is not an important contributor to the apparent dearth of N-rich stars. Our [C/N] values are in the same range as values reported previously in the literature (-0.5 to $+2.0$), and all stars are in disagreement with the predicted [C/N] ratios for both low-mass and high-mass AGB stars. We suggest that the decrease in [C/N] from the low-mass AGB models is due to enhanced extra-mixing, while the lack of NEMP stars may be caused by unfavorable mass ratios in binaries or the difficulty of mass transfer in binary systems with large mass ratios.

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The *Spitzer* Survey of the Small Magellanic Cloud: S^{3}MC Imaging and Photometry in the Mid- and Far-Infrared Wavebands

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We present the initial results from the *Spitzer* Survey of the Small Magellanic Cloud (S^{3}MC), which imaged the star-forming body of the Small Magellanic Cloud (SMC) in all seven MIPS and IRAC wavebands. We find that the F_8/F_{24} ratio (an estimate of PAH abundance) has large spatial variations and takes a wide range of values that are unrelated to metallicity but anticorrelated with 24 μm brightness and F_{24}/F_{70} ratio. This suggests that photodestruction is primarily responsible for the low abundance of PAHs observed in star-forming low-metallicity galaxies. We use the S^{3}MC images to compile a photometric catalog of $\sim 400,000$ mid- and far-infrared point sources in the SMC. The sources detected at the longest wavelengths fall into four main categories: 1) bright 5.8 μm sources with very faint optical counterparts and very red mid-infrared colors ($[5.8]-[8.0] > 1.2$), which we identify as YSOs. 2) Bright mid-infrared sources with mildly red colors ($0.16 \lesssim [5.8]-[8.0] < 0.6$), identified as carbon stars. 3) Bright mid-infrared sources with neutral colors and bright optical counterparts, corresponding to oxygen-rich evolved stars. And, 4) unreddened early B stars (B3 to O9) with a large 24 μm excess. This excess is reminiscent of debris disks, and is detected in only a small fraction of these stars ($\lesssim$5%). The majority of the brightest infrared point sources in the SMC fall into groups one to three. We use this photometric information to produce a catalog of 282 bright YSOs in the SMC with a very low level of contamination ($\sim$ 7%).

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3D-Spectroscopy of extragalactic planetary nebulae as diagnostic probes for galaxy evolution

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In addition to study extragalactic stellar populations in their integrated light, the detailed analysis of individual resolved objects has become feasible, mainly for luminous giant stars and for extragalactic planetary nebulae (XPNe) in nearby galaxies. A recently started project at the Astrophysical Institute Potsdam (AIP), called "XPN–Physics", aims to verify if XPNe are useful probes to measure the chemical abundances of their parent stellar population. The project involves theoretical and observational work packages.

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Nebular emission lines in IRAS 17347–3139

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We report the detection of nebular emission lines in the optical and mid-infrared spectra of IRAS 17347–3139, a heavily obscured OH/IR star which may be rapidly evolving from the AGB to the PN stage. The presence of emission lines is interpreted as a clear indication that the ionization of its circumstellar envelope has already started. This source belongs to the rare class of objects known as 'OHPNe' displaying both OH maser and radio continuum emission. However, unlike the rest of stars in this class, prominent C-rich dust features are detected in its mid-infrared spectrum, which makes the analysis of this star particularly interesting.

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Thesis

Light Neutron-Capture Element Abundances in Planetary Nebulae

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This dissertation presents a spectroscopic study of light neutron(n)-capture elements in Galactic planetary nebulae (PNe). The abundances of n-capture elements may be enhanced in PNe if their progenitor stars experienced s-process nucleosynthesis and third dredge-up (TDU) during the asymptotic giant branch (AGB) phase. We derive the abundances of Ge, Se, and Kr in PNe from ultraviolet (UV) and near-infrared (NIR) spectroscopic observations. We detect Ge III in absorption against the central star UV continua of six PNe, and derive Ge abundances for five of these objects. Four of these PNe exhibit Ge abundances enriched by a factor of $\geq$ 3–10, depending on the level of Ge depletion into dust, which provides evidence for the occurrence of the s-process in their progenitor stars. We have observed 103 PNe in the NIR with the CoolSpec spectrometer at McDonald Observatory, to search for emission lines of [Se IV] and [Kr III]. Including NIR spectra of 17 PNe from the literature, Se and/or Kr are detected in 81 of 120 objects. We construct a grid of photoionization models to derive widely applicable formulae that can be used to correct for the abundances of unobserved Se and Kr ions. These correction factors are used to determine the Se and Kr elemental abundances of PNe in our sample. We find that Se and Kr are enriched relative to solar in 35 of the 78 PNe with determined Se and Kr abundances, and hence their progenitor stars experienced the s-process and TDU during the AGB phase. Type I and bipolar PNe, which have intermediate-mass ($>$ 3–4 $M_{\odot}$) progenitors, are far less enriched in Se and Kr than other PNe, indicating that intermediate-mass AGB stars do not experience significant s-process enrichments. The Se and Kr abundances are correlated with nebular C/O ratios, as theoretically expected. We estimate that at least 20% of Galactic PNe experienced s-process nucleosynthesis and TDU, by constructing a PN luminosity function for our sample and correcting it for completeness at faint luminosities. This study comprises the first large-scale survey of n-capture elements in PNe, and significantly increases the number of PNe with known n-capture element abundances.

327 pages, available upon request from sterling@astro.as.utexas.edu