THE AGB NEWSLETTER

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

Official publication of the IAU Working Group on Abundances in Red Giants

No. 159 — 2 October 2010

http://www.astro.keele.ac.uk/AGBnews

Editors: Jacco van Loon and Albert Zijlstra

Editorial

Dear Colleagues,

It is our pleasure to present you the 159$^{\rm th}$ issue of the AGB Newsletter, with more contributions than usually (or ever?). Partly to "blame" is the fifth meeting aimed at understanding what makes many planetary nebulae appear asymmetric. No doubt there will be a sixth. Other interesting developments include models of Alfvén-wave-driven winds, two groups looking into the formation of fullerenes in space, confirmation that Mira's companion really is a white dwarf, detection of a magnetic field on an M5-type giant, and the release of the MESA star 1-D stellar evolution code, and lots more.

The next issue is planned to be distributed on the 2$^{\rm nd}$ of November 2010.

Editorially Yours,
Jacco van Loon and Albert Zijlstra

Food for Thought

This month's thought-provoking statement is:

Where is the evidence for Mira's ancient novae, and when will be the next?

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

White dwarf – red dwarf systems resolved with the *Hubble* Space Telescope. II. Full snapshot survey results

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Results are presented for a *Hubble* Space Telescope Advanced Camera for Surveys high-resolution imaging campaign of 90 white dwarfs with known or suspected low mass stellar and substellar companions. Of the 72 targets which remain candidate and confirmed white dwarfs with near-infrared excess, 43 are spatially resolved into two or more components, and a total of 12 systems are potentially triples. For 68 systems where a comparison is possible, 50% have significant photometric distance mismatches between their white dwarf and M dwarf components, suggesting white dwarf parameters derived spectroscopically are often biased due to the cool companion. Interestingly, nine of 30 binaries known to have emission lines are found to be visual pairs and hence widely separated, indicating an intrinsically active cool star and not irradiation from the white dwarf. There is a possible, slight deficit of earlier spectral types (bluer colors) among the spatially unresolved companions, exactly the opposite of expectations if significant mass is transferred to the companion during the common envelope phase.
Using the best available distance estimates, the low mass companions to white dwarfs exhibit a bimodal distribution in projected separation. This result supports the hypothesis that during the giant phases of the white dwarf progenitor, any unevolved companions either migrate inward to short periods of hours to days, or outward to periods of hundreds to thousands of years. No intermediate projected separations of a few to several AU are found among these pairs. However, a few double M dwarfs (within triples) are spatially resolved in this range, empirically demonstrating that such separations were readily detectable among the binaries with white dwarfs. A straightforward and testable prediction emerges: all spatially unresolved, low mass stellar and substellar companions to white dwarfs should be in short period orbits. This result has implications for substellar companion and planetary orbital evolution during the post-main sequence lifetime of their stellar hosts.

Accepted for publication in ApJS
Available from arXiv:1008.2545

3.6 Years of DIRBE near-infrared stellar light curves

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The weekly averaged near-infrared fluxes for 2652 stars were extracted from the cold and warm era all-sky maps of the Diffuse Infrared Background Experiment (DIRBE). Since the DIRBE program only archived the individual Calibrated Infrared Observations for the 10 month cold era mission, the weekly averaged fluxes were all that were available for the warm era. The steps required to extract stellar fluxes are described as are the adjustments that were necessary to correct the results for several systematic effects. The observations are at a cadence of once a week for 3.6 years ($\sim$ 1300 days), providing continuous sampling on variable stars that span the entire period for the longest fundamental pulsators. The stars are divided into three categories: those with large amplitude of variability, smaller amplitude variables and sources whose near-infrared brightness do not vary according to our classification criteria. We show examples of the results and the value of the added baseline in determining the phase lag between the visible and infrared.

Accepted for publication in Astrophysical Journal Supplement

Is there a metallicity gradient in the Large Magellanic Cloud?

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A small but significant radial gradient in the mean periods of Large Magellanic Cloud (LMC) RR Lyrae variables is established from the OGLE-III survey data. This is interpreted as a metallicity gradient but other possibilities are also discussed. Data on the ratio of photometrically selected C- and M-type asymptotic giant branch (AGB) stars in the LMC, kindly provided by M-R.L. Cioni, are reanalysed. Removing the effects of bias leads to conclusions strikingly different to the original ones. There is a slight gradient of the C/M ratio in the inner part of the LMC, which might be due to a very small mean metallicity gradient. In the outer part of the LMC the C/M ratio drops dramatically. The most likely reason for this is that the proportion of older stars increases in the outer regions. The mean metallicity of the inner AGB star population estimated from the C/M ratio is lower than for intermediate age LMC clusters and suggest that this population is in the mean older than the clusters and has a mean age which falls in the LMC cluster age gap.

Published in MNRAS Letters (early view)
Available from arXiv:1008.2274

Solar-like oscillations in red giants observed with *Kepler*: comparison of global oscillation parameters from different methods

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The large number of stars for which uninterrupted high-precision photometric timeseries data are being collected with *Kepler* and CoRoT initiated the development of automated methods to analyse the stochastically excited oscillations in main-sequence, subgiant and red-giant stars. Aims: We investigate the differences in results for global oscillation parameters of G and K red-giant stars due to different methods and definitions. We also investigate uncertainties originating from the stochastic nature of the oscillations. Methods: For this investigation we use *Kepler* data obtained during the first four months of operation. These data have been analysed by different groups using already published methods and the results are compared. We also performed simulations to investigate the uncertainty on the resulting parameters due to different realizations of the stochastic signal. Results: We obtain results for the frequency of maximum oscillation power ($\nu_{\rm max}$) and the mean large separation ($\langle\Delta\nu\rangle$) from different methods for over one thousand red-giant stars. The results for these parameters agree within a few percent and seem therefore robust to the different

analysis methods and definitions used here. The uncertainties for $\nu_{\max}$ and $\langle\Delta\nu\rangle$ due to differences in realization noise are not negligible and should be taken into account when using these results for stellar modelling.

Accepted for publication in A&A
Available from arXiv:1008.2959

Winds from luminous late-type stars: II. Broadband frequency distribution of Alfvén waves

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We present the numerical simulations of winds from evolved giant stars using a fully non-linear, time dependent 2.5-dimensional magnetohydrodynamic (MHD) code. This study extends our previous fully non-linear MHD wind simulations to include a broadband frequency spectrum of Alfvén waves that drive winds from red giant stars. We calculated four Alfvén wind models that cover the whole range of Alfvén wave frequency spectrum to characterize the role of freely propagated and reflected Alfvén waves in the gravitationally stratified atmosphere of a late-type giant star. Our simulations demonstrate that, unlike linear Alfvén wave-driven wind models, a stellar wind model based on plasma acceleration due to broadband non-linear Alfvén waves, can consistently reproduce the wide range of observed radial velocity profiles of the winds, their terminal velocities and the observed mass loss rates. Comparison of the calculated mass loss rates with the empirically determined mass loss rate for α Tau suggests an anisotropic and time-dependent nature of stellar winds from evolved giants.

Accepted for publication in Astrophysical Journal
Available from arXiv:1008.3955

Rapidly decaying supernova 2010X: A candidate ".Ia" explosion

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We present the discovery, photometric and spectroscopic follow-up observations of SN 2010X (PTF 10bhp). This supernova decays exponentially with $\tau_{\rm d} = 5$ days, and rivals the current recordholder in speed, SN 2002bj. SN 2010X

peaks at $M_r = -17$ mag and has mean velocities of 10,000 km s^{-1}. Our light curve modeling suggests a radioactivity powered event and an ejecta mass of 0.16 $M_\odot$. If powered by Nickel, we show that the Nickel mass must be very small (0.02 $M_\odot$) and that the supernova quickly becomes optically thin to γ-rays. Our spectral modeling suggests that SN 2010X and SN 2002bj have similar chemical compositions and that one of Aluminum or Helium is present. If Aluminum is present, we speculate that this may be an accretion induced collapse of an O–Ne–Mg white dwarf. If Helium is present, all observables of SN 2010X are consistent with being a thermonuclear Helium shell detonation on a white dwarf, a ".Ia" explosion. With the 1-day dynamic-cadence experiment on the Palomar Transient Factory, we expect to annually discover a few such events.

Submitted to ApJL
Available from arXiv:1009.0960

Modules for Experiments in Stellar Astrophysics (MESA)

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Stellar physics and evolution calculations enable a broad range of research in astrophysics. Modules for Experiments in Stellar Astrophysics (MESA) is a suite of open source libraries for a wide range of applications in computational stellar astrophysics. A newly designed 1-D stellar evolution module, MESA star, combines many of the numerical and physics modules for simulations of a wide range of stellar evolution scenarios ranging from very-low mass to massive stars, including advanced evolutionary phases. MESA star solves the fully coupled structure and composition equations simultaneously. It uses adaptive mesh refinement and sophisticated timestep controls, and supports shared memory parallelism based on OpenMP. Independently usable modules provide equation of state, opacity, nuclear reaction rates, and atmosphere boundary conditions. Each module is constructed as a separate Fortran 95 library with its own public interface. Examples include comparisons to other codes and show evolutionary tracks of very low mass stars, brown dwarfs, and gas giant planets; the complete evolution of a 1 $M_\odot$ star from the pre-main sequence to a cooling white dwarf; the Solar sound speed profile; the evolution of intermediate mass stars through the thermal pulses on the He-shell burning AGB phase; the interior structure of slowly pulsating B Stars and β Cepheids; evolutionary tracks of massive stars from the pre-main sequence to the onset of core collapse; stars undergoing Roche lobe overflow; and accretion onto a neutron star. Instructions for downloading and installing MESA can be found on the project web site (http://mesa.sourceforge.net).

Submitted to ApJS
Available from arXiv:1009.1622
and from http://mesa.sourceforge.net

Three-dimensional hydrodynamical simulations of red giant stars: semi-global models for the interpretation of interferometric observations

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Context. Theoretical predictions from models of red giant branch stars are a valuable tool for various applications in astrophysics ranging from galactic chemical evolution to studies of exoplanetary systems. Aims. We use the radiative

transfer code Optim3D and realistic 3D radiative-hydrodynamical (RHD) surface convection simulations of red giants to explore the impact of granulation on interferometric observables. We assess how 3D simulations of surface convection can be validated against observations.
Methods. We compute intensity maps for the 3D simulation snapshots in two filters: in the optical at 5000 ± 300 Å and in the K band 2.14 ± 0.26 μm FLUOR filter, corresponding to the wavelength-range of instruments mounted on the CHARA interferometer. From the intensity maps, we construct images of the stellar disks, accounting for center-to-limb variations. We then derive interferometric visibility amplitudes and phases. We study their behavior with position angle and wavelength, and compare them with CHARA observations of the red giant star HD 214868.
Results. We provide average limb-darkening coefficients for different metallicities and wavelength-ranges. We detail the prospects for the detection and characterization of granulation and center-to-limb variations of red giant stars with today's interferometers. Regarding interferometric observables, we find that the effect of convective-related surface structures depends on metallicity and surface gravity. We provided theoretical closure phases that should be incorporated into the analysis of red giant planet companion closure phase signals. We estimate 3D–1D corrections to stellar radii determination: 3D models are $\sim 3.5\%$ smaller to $\sim 1\%$ larger in the optical with respect to 1D, and roughly 0.5 to 1.5% smaller in the infrared. Even if these corrections are small, they are important to properly set the zero point of effective temperature scale derived by interferometry and to strengthen the confidence of existing red giant catalogues of calibrating stars for interferometry. Finally, we show that our RHD simulations provide an excellent fit to the red giant HD 214868 even though more observations are needed at higher spatial frequencies and shorter wavelength.

Accepted for publication in Astronomy and Astrophysics
Available from arXiv:1009.1745

Photodissociation in proto-planetary nebulae. Hydrodynamical simulations and solutions for low-velocity multi-lobes

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We explore the effects of photodissociation at the stages of post-asymptotic giant branch stars to find a mechanism able to produce multi-polar shapes. We perform two-dimensional gasdynamical simulations to model the effects of photodissociation in proto-planetary nebulae. We find that post-asymptotic giant branch stars with $\sim 7,000$ K or hotter are able to photodissociate a large amount of the circumstellar gas. We compute several solutions for nebulae with low-velocity multi-lobes. We find that the early expansion of a dissociation front is crucial to understand the number of lobes in proto-planetary nebulae. A dynamical instability appears when cooling is included in the swept-up molecular shell. This instability is similar to the one found in photoionization fronts, and it is associated with the thin-shell Vishniac instability. The dissociation front exacerbates the growth of the thin-shell instability, creating a fast fragmentation in shells expanding into media with power-law density distributions such as r^{-2}.

Accepted for publication in Astronomy and Astrophysics Letters
Available from arXiv:1009.2066

Chemical composition of the RS CVn-type star λ Andromedae

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Photospheric parameters and chemical composition are determined for the single-lined chromospherically active RS CVn-type star λ And (HD 222107). From the high resolution spectra obtained on the Nordic Optical Telescope, abundances of 22 chemical elements and isotopes, including such key elements as ^{12}C, ^{13}C, N and O, were investigated. The differential line analysis with the MARCS model atmospheres gives $T_{\rm eff}$ = 4830 K, $\log g$ = 2.8, [Fe/H] = −0.53, [C/Fe] = 0.09, [N/Fe] = 0.35, [O/Fe] = 0.45, C/N = 2.21, ^{12}C/^{13}C = 14. The value of ^{12}C/^{13}C ratio for a star of the RS CVn-type is determined for the first time, and its low value gives a hint that extra-mixing processes may start acting in low-mass chromospherically active stars below the bump of the luminosity function of red giants.

Accepted for publication in Baltic Astronomy, 19, 95 (2010)
Available from arXiv:1009.0903
and from http://adsabs.harvard.edu/abs/2010BaltA..19...95T

The evolution of planetary nebulae VII. Modelling planetary nebulae of distant stellar systems

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By means of hydrodynamical models we do the first investigations of how the properties of planetary nebulae are affected by their metal content and what can be learned from spatially unresolved spectrograms of planetary nebulae in distant stellar systems. We computed a new series of 1D radiation-hydrodynamics planetary nebulae model sequences with central stars of 0.595 $M_\odot$ surrounded by initial envelope structures that differ only by their metal content. At selected phases along the evolutionary path, the hydrodynamic terms were switched off, allowing the models to relax for fixed radial structure and radiation field into their equilibrium state with respect to energy and ionisation. The analyses of the line spectra emitted from both the dynamical and static models enabled us to systematically study the influence of hydrodynamics as a function of metallicity and evolution. We also recomputed selected sequences already used in previous publications, but now with different metal abundances. These sequences were used to study the expansion properties of planetary nebulae close to the bright cut-off of the planetary nebula luminosity function. Our simulations show that the metal content strongly influences the expansion of planetary nebulae: the lower the metal content, the weaker the pressure of the stellar wind bubble, but the faster the expansion of the outer shell because of the higher electron temperature. This is in variance with the predictions of the interacting-stellar-winds model (or its variants) according to which only the central-star wind is thought to be responsible for driving the expansion of a planetary nebula. Metal-poor objects around slowly evolving central stars become very dilute and are prone to depart from thermal equilibrium because then adiabatic expansion contributes to gas cooling. We find indications that photoheating and line cooling are not fully balanced in the evolved planetary nebulae of the Galactic halo. Expansion rates based on widths of volume-integrated line profiles computed from our radiation-hydrodynamics models compare very well with observations of distant stellar system. Objects close to the bright cut-off of the planetary nebula luminosity function consist of rather massive central stars (> 0.6 $M_\odot$) with optically thick (or nearly thick) nebular shells. The half-width-half-maximum velocity during this bright phase is virtually independent of metallicity, as observed, but somewhat depends on the final AGB-wind parameters. The observed expansion properties of planetary nebulae in distant stellar systems with different metallicities are explained very well by our 1D radiation-hydrodynamics models. This result demonstrates convincingly that the formation and acceleration of a planetary nebula occurs mainly because of ionisation and heating of the circumstellar matter by the stellar radiation field, and that the pressure exerted by the shocked stellar wind is less important. Determinations of nebular abundances by means of photoionisation modelling may become problematic for those cases where expansion cooling must be considered.

Accepted for publication in Astronomy & Astrophysics
Available from arXiv:1009.0999

Near-infrared integrated spectra of Galactic globular clusters: testing simple stellar population models

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We present SOAR/OSIRIS cross-dispersed NIR integrated spectra of 12 Galactic globular clusters that are employed to test Maraston (2005, M05) NIR EPS models, and to provide spectral observational constraints to calibrate future models. We measured Ew of the most prominent NIR absorption features. Optical Ew were also measured. The globular clusters Ew were compared with model predictions with ages within 4–15 Gyr, and metallicities between 1/200 and 2 $Z_{\odot}$. Observed integrated colours were also compared with models. The NIR integrated spectra among our sample appear qualitatively similar in most the absorption features. The M05 models can properly predict the optical Ew observed in globular clusters. Regarding the NIR, they do underestimate the strength of Mg I 1.49 μm, but they can reproduce the observed Ew of Fe I 1.58 μm, Si I 1.59 μm, and CO 2.29 μm, in about half of our sample. The remaining objects require the inclusion of intermediate-age populations. Thus, we suggest that the presence of C- and O-rich stars in models is important to reproduce the observed strengths of metallic lines. Another possibility is the lack of alpha-enhancement in the models. In the case of the optical and NIR Fe I lines, standard models and those that include blue horizontal branch stars, produce similar results. A similar trend is observed for Na I 5895 Å, while in the case of the G-band, the models with blue horizontal branch do describe better the observations. For most of the sample the optical to NIR colours are well described by the M05 models. In general, M05 models can provide reliable information on the NIR stellar population of galaxies, but only when Ew and colours are taken together, in other words, Ew and continuum fluxes should be simultaneously fitted. However, the results should be taken with caution, since the models tend to predict results biased towards young ages.

Accepted for publication in MNRAS
Available from arXiv:1009.1089

Evidence for a sharp structure variation inside a red-giant star

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The availability of precisely determined frequencies of radial and non-radial oscillation modes in red giants is finally paving the way for detailed studies of the internal structure of these stars. We look for the seismic signature of regions of sharp structure variation in the internal structure of the CoRoT target HR 7349. We analyse the frequency dependence of the large frequency separation and second frequency differences, as well as the behaviour of the large frequency separation obtained with the envelope auto-correlation function. We find evidence for a periodic component in the oscillation frequencies, i.e. the seismic signature of a sharp structure variation in HR 7349. In a comparison with stellar models we interpret this feature as caused by a local depression of the sound speed that occurs in the helium second-ionization region. Using solely seismic constraints this allows us to estimate the mass ($M = 1.2^{+0.6}_{-0.4}$ $M_{\odot}$) and radius ($R = 12.2^{+2.1}_{-1.8}$ $R_{\odot}$) of HR 7349, which agrees with the location of the star in an HR diagram.

Accepted for publication in A&A Letters
Available from arXiv:1009.1024
and from http://www.aanda.org/articles/aa/pdf/forth/aa15442-10.pdf

The Necklace: equatorial and polar outflows from the binary central star of the new planetary nebula IPHASX J194359.5+170901

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IPHASX J194359.5+170901 is a new high-excitation planetary nebula with remarkable characteristics. It consists of a knotty ring expanding at a speed of 28 km s^{-1}, and a fast collimated outflow in the form of faint lobes and caps along the direction perpendicular to the ring. The expansion speed of the polar caps is $\sim$ 100 km s^{-1}, and their kinematical age is twice as large as the age of the ring.

Time-resolved photometry of the central star of IPHASX J194359.5+170901 reveals a sinusoidal modulation with a period of 1.16 days. This is interpreted as evidence for binarity of the central star, the brightness variations being related to the orbital motion of an irradiated companion. This is supported by the spectrum of the central star in the visible range, which appears to be dominated by emission from the irradiated zone, consisting of a warm (6000–7000 K) continuum, narrow C III, C IV, and N III emission lines, and broader lines from a flat H I Balmer sequence in emission.

IPHASX J194359.5+170901 helps to clarify the role of (close) binaries in the formation and shaping of planetary nebulae. The output of the common-envelope evolution of the system is a strongly flattened circumstellar mass deposition, a feature that seems to be distinctive of this kind of binary system. Also, IPHASX J194359.5+170901 is among the first post-CE PNe for which the existence of a high-velocity polar outflow has been demonstrated. Its kinematical age might indicate that the polar outflow is formed before the common-envelope phase. This points to mass transfer onto the secondary as the origin, but alternative explanations are also considered.

Accepted for publication in M.N.R.A.S.
Available from arXiv:1009.1043

K 3-22: a D-type symbiotic star

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A goal of the IPHAS survey is to determine the frequency and nature of emission-line sources in the Galactic plane. According to our selection criteria, K 3-22 is a candidate symbiotic star, but it was previously classified as a planetary nebula. To determine its nature, we acquired a low-resolution optical spectrum of K 3-22. Our analysis of our spectroscopy demonstrates that K 3-22 is indeed a D-type symbiotic star, because of its high excitation nebular spectrum and the simultaneous presence of Raman-scattered O VI emission at 6825 and 7082 Å, which is detected primarily in symbiotic stars.

Accepted for publication in Astronomy and Astrophysics

Planetary nebulae in the elliptical galaxy NGC 821: kinematics and distance determination

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Using a slitless spectroscopy method with the 8.2 m Subaru telescope and its FOCAS Cassegrain spectrograph, we have increased the number of planetary nebula (PN) detections and PN velocity measurements in the flattened elliptical galaxy NGC 821. A comparison with the detections reported previously by the Planetary Nebula Spectrograph (PN.S) group indicates that we have confirmed most of their detections. The velocities measured by the two groups, using different telescopes, spectrographs and slitless techniques, are in good agreement. We have built a combined sample of 167 PNs and have confirmed the keplerian decline of the line-of-sight velocity dispersion reported previously. We also confirm misaligned rotation from the combined sample. A dark matter halo may exist around this galaxy, but it is not needed to keep the PN velocities below the local escape velocity as calculated from the visible mass. We have measured the m(5007) magnitudes of 145 PNs and produced a statistically complete sample of 40 PNs in NGC 821. The resulting PN luminosity function (PNLF) was used to estimate a distance modulus of 31.4 mag, equivalent to 19 Mpc. We also estimated the PN formation rate. NGC 821 becomes the most distant galaxy with a PNLF distance determination. The PNLF distance modulus is smaller than the surface brightness fluctuation (SBF) distance modulus by 0.4 mag. Our kinematic information permits to rule out the idea that a shorter PNLF distance could be produced by the contamination of the PNLF by background galaxies with emission lines redshifted into the on-band filter transmission curve.

Published in ApJ
Available from arXiv:1008.2237

Formation of fullerenes in H-containing Planetary Nebulae

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Hydrogen depleted environments are considered an essential requirement for the formation of fullerenes. The recent detection of C60 and C70 fullerenes in what was incorrectly interpreted as the hydrogen-poor inner region of a post-final helium shell flash Planetary Nebula (PN) seemed to confirm this picture. Here, we present strong evidence that challenges the current paradigm regarding fullerene formation, showing that it can take place in circumstellar environments containing hydrogen. We report the simultaneous detection of Polycyclic Aromatic Hydrocarbons (PAHs) and fullerenes towards C-rich and H-containing PNe belonging to environments with very different chemical histories such as our own Galaxy and the Small Magellanic Cloud. We suggest that PAHs and fullerenes may be formed by the photochemical processing of hydrogenated amorphous carbon. These observations have profound implications on our current understanding of the chemistry of large organic molecules as well as the chemical processing in space.

Accepted for publication in The Astrophysical Journal Letters
Available from arXiv:1009.4357
and from http://www.iac.es/folleto/research/preprints/?c=view&pre_id=10066

Detection of C60 and C70 in a young Planetary Nebula

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In recent decades, a number of molecules and diverse dust features have been identified by astronomical observations in various environments. Most of the dust that determines the physical and chemical characteristics of the interstellar medium is formed in the outflows of asymptotic giant branch stars and is further processed when these objects become planetary nebulae. We studied the environment of Tc 1, a peculiar planetary nebula whose infrared spectrum shows emission from cold and neutral C60 and C70. The two molecules amount to a few percent of the available cosmic carbon in this region. This finding indicates that if the conditions are right, fullerenes can and do form efficiently in space.

Published in Science

The mass-loss return from evolved stars to the Large Magellanic Cloud III. Dust properties for carbon-rich asymptotic giant branch stars

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We present a radiative transfer model for the circumstellar dust shell around a Large Magellanic Cloud (LMC) long-period variable (LPV) previously studied as part of the Optical Gravitational Lensing Experiment (OGLE) survey of the LMC. OGLE LMC LPV 28579 (SAGE J051306.40−690946.3) is a carbon-rich asymptotic giant branch (AGB) star for which we have Spitzer broadband photometry and spectra from the SAGE and SAGE-Spec programs along with broadband UBVIJHKs photometry. By modeling this source, we obtain a baseline set of dust properties to be used in the construction of a grid of models for carbon stars. We reproduce the spectral energy distribution of the source using a mixture of amorphous carbon and silicon carbide with 15% SiC by mass. The grain sizes are distributed according to the KMH model, with $\gamma = 3.5$, $a_{\rm min} = 0.01$ μm and $a_0 = 1.0$ μm. The best-fit model produces an optical depth of 0.28 for the dust shell at the peak of the SiC feature (11.3 μm), with an inner radius of about 1430 $R_\odot$ or 4.4 times the stellar radius. The temperature at this inner radius is 1310 K. Assuming an expansion velocity of 10 km s^{-1}, we obtain a dust mass-loss rate of 2.5×10^{-9} $M_\odot$ yr^{-1}. We calculate a 15% variation in this mass-loss rate by testing the sensitivity of the fit to variation in the input parameters. We also present a simple model for the molecular gas in the extended atmosphere that could give rise to the 13.7 μm feature seen in the spectrum. We find that a combination of CO and C_2H_2 gas at an excitation temperature of about 1000 K and column densities of 3×10^{21} cm^{-2} and 10^{19} cm^{-2} respectively are able to reproduce the observations. Given that the excitation temperature is close to the temperature of the dust at the inner radius, most of the molecular contribution probably arises from this region. The luminosity corresponding to the first epoch of SAGE observations is 6580 $L_\odot$. For an effective temperature of about 3000 K, this implies a stellar mass of 1.5–2 $M_\odot$ and an age of 1–2.5 Gyr for OGLE LMC LPV 28579. We calculate a gas mass-loss

rate of 5.0×10^{-7} $M_\odot$ yr^{-1} assuming a gas:dust ratio of 200. This number is comparable to the gas mass-loss rates estimated from the period, color and 8 μm flux of the source.

Accepted for publication in Astronomy & Astrophysics
Available from arXiv:1009.2681

Evidence of V-band polarimetric separation of carbon stars at high Galactic latitude

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Polarization is an important indicator of stellar evolution, especially for stars evolving from red-giant stage to planetary nebulae. However, not much is known about the polarimetric properties of the carbon-enhanced metal-poor (CEMP) stars, although they have been well studied in terms of photometric as well as low- and high-resolution spectroscopy. We report here first-ever estimates of V-band polarimetry of a group of CEMP stars. V-band polarimetry was planned as the V-band is known to show maximum polarization among BVRI polarimetry for any scattering of light caused due to dust. Based on these estimates the program stars show a distinct classification into two: one with $p\% < 0.4$ and the other with $p\% > 1$. Stars with circumstellar material exhibit a certain amount of polarization that may be caused by scattering of starlight due to circumstellar dust distribution into non-spherically symmetric envelopes. The degree of polarization increases with asymmetries present in the geometry of the circumstellar dust distribution. Our results reflect upon these properties. While the sample size is relatively small, the polarimetric separation of the two groups ($p\% < 0.4$ and $p\% > 1$) is very distinct; this finding, therefore, opens up an avenue of exploration with regard to CEMP stars.

Published in The Astrophysical Journal Letters, 722, 90 (2010)
Available from arXiv:1009.3912

Abundances of Galactic anticenter Planetary Nebulae and the oxygen abundance gradient in the Galactic disk

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We have obtained spectrophotometric observations of 41 anticenter planetary nebulae (PNe) located in the disk of the Milky Way. Electron temperatures and densities, as well as chemical abundances for He, N, O, Ne, S, Cl, and Ar were determined. Incorporating these results into our existing database of PN abundances yielded a sample of 124 well-observed objects with homogeneously-determined abundances extending from 0.9–21 kpc in Galactocentric distance. We performed a detailed regression analysis which accounted for uncertainties in both oxygen abundances and radial distances in order to establish the metallicity gradient across the disk to be: $12+\log(\mathrm{O/H}) = (9.09\pm0.05) - (0.058 \pm 0.006) \times R_\mathrm{g}$, with R_g in kpc. While we see some evidence that the gradient steepens at large galactocentric distances, more objects toward the anticenter need to be observed in order to confidently establish the true form of the metallicity gradient. We find no compelling evidence that the gradient differs between Peimbert Types I and II, nor is oxygen abundance related to the vertical distance from the Galactic plane. Our gradient agrees well with analogous

results for H II regions but is steeper than the one recently published by Stanghellini & Haywood (2010) over a similar range in Galactocentric distance. A second analysis using PN distances from a different source implied a flatter gradient, and we suggest that we have reached a confusion limit which can only be resolved with greatly improved distance measurements and an understanding of the natural scatter in oxygen abundances. Finally, a consideration of recently published chemical evolution models of the Galactic disk suggests that reconciling the current range in published oxygen gradients is necessary for adequately constraining parameters such as the surface density threshold for star formation and the characteristic timescale for disk formation.

Accepted for publication in Astrophysical Journal
Available from arXiv:1009.1921

Evidence for the white dwarf nature of Mira B

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The nature of the accreting companion to Mira — the prototypical pulsating asymptotic giant branch star — has been a matter of debate for more than 25 years. Here we use a quantitative analysis of the rapid optical brightness variations from this companion, Mira B, which we observed with the Nickel telescope at Lick Observatory, to show that it is a white dwarf (WD). The amplitude of aperiodic optical variations on time scales of minutes to tens of minutes (≈ 0.2 mag) is consistent with that of accreting WDs in cataclysmic variables on these same time scales. It is significantly greater than that expected from an accreting main-sequence star. With Mira B identified as a WD, its ultraviolet (UV) and optical luminosities, along with constraints on the WD effective temperature from the UV, indicate that it accretes at $\sim 10^{-10}$ $M_\odot$ yr^{-1}. We do not find any evidence that the accretion rate is higher than predicted by Bondi–Hoyle theory. The accretion rate is high enough, however, to explain the weak X-ray emission, since the accretion-disk boundary layer around a low-mass WD accreting at this rate is likely to be optically thick and therefore to emit primarily in the far or extreme UV. Furthermore, the finding that Mira B is a WD means that it has experienced, and will continue to experience nova explosions, roughly every 10^6 years. It also highlights the similarity between Mira AB and other jet-producing symbiotic binaries such as R Aquarii, CH Cygni, and MWC 560, and therefore raises the possibility that Mira B launched the recently discovered bipolar streams from this system.

Accepted for publication in ApJ
Available from arXiv:1009.2509

The ACS Nearby Galaxy Survey Treasury IX. Constraining asymptotic giant branch evolution with old metal-poor galaxies

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In an attempt to constrain evolutionary models of the asymptotic giant branch (AGB) phase at the limit of low masses

and low metallicities, we have examined the luminosity functions and number ratio between AGB and red giant branch (RGB) stars from a sample of resolved galaxies from the ACS Nearby Galaxy Survey Treasury (ANGST). This database provides HST optical photometry together with maps of completeness, photometric errors, and star formation histories for dozens of galaxies within 4 Mpc. We select 12 galaxies characterized by predominantly metal-poor populations as indicated by a very steep and blue RGB, and which do not present any indication of recent star formation in their color–magnitude diagrams. Thousands of AGB stars brighter than the tip of the RGB (TRGB) are present in the sample (between 60 and 400 per galaxy), hence the Poisson noise has little impact in our measurements of the AGB/RGB ratio. We model the photometric data with a few sets of thermally pulsing AGB (TP-AGB) evolutionary models with different prescriptions for the mass loss. This technique allows us to set stringent constraints to the TP-AGB models of low-mass metal-poor stars (with $M < 1.5$ $M_{\odot}$, [Fe/H] $\lesssim -1.0$). Indeed, those which satisfactorily reproduce the observed AGB/RGB ratios have TP-AGB lifetimes between 1.2 and 1.8 Myr, and finish their nuclear burning lives with masses between 0.51 and 0.55 $M_{\odot}$. This is also in good agreement with recent observations of white dwarf masses in the M4 old globular cluster. These constraints can be added to those already derived from Magellanic Cloud star clusters as important mileposts in the arduous process of calibrating AGB evolutionary models.

Accepted for publication in The Astrophysical Journal
Available from arXiv:1009.4618

The symbiotic system AG Draconis. Soft X-ray bremsstrahlung from the nebulae

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The modelling of UV and optical spectra emitted from the symbiotic system AG Draconis, adopting collision of the winds, predicts soft X-ray bremsstrahlung from nebulae downstream of the reverse shock with velocities > 150 km s^{-1} and intensities comparable to those of the white dwarf black body flux. At outbursts, the envelop of debris, which corresponds to the nebula downstream of the high velocity shocks (700–1000 km s^{-1}) accompanying the blast wave, absorbs the black body soft X-ray flux from the white dwarf, explains the broad component of the H and He lines, and leads to low optical–UV–X-ray continuum fluxes. The high optical–UV flux observed at the outbursts is explained by bremsstrahlung downstream of the reverse shock between the stars. The depletion of C, N, O, and Mg relative to H indicates that they are trapped into dust grains and/or into diatomic molecules, suggesting that the collision of the wind from the white dwarf with the dusty shells, ejected from the red giant with about 1 year periodicity, leads to the U-band fluctuations during the major bursts.

Accepted for publication in New Astronomy
Available from arXiv:1009.3209

The exotic eclipsing nucleus of the ring Planetary Nebula SuWt 2

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SuWt 2 is a planetary nebula (PN) consisting of a bright ionized thin ring seen nearly edge-on with much fainter bipolar lobes extending perpendicularly to the ring. It has a bright (12^{th}-mag) central star, too cool to ionize the PN,

which we discovered in the early 1990s to be an eclipsing binary. Although it was anticipated that there would also be an optically faint, hot, ionizing star in the system, a spectrum from the *International Ultraviolet Explorer* (*IUE*) did not reveal a UV source. We present extensive ground-based photometry and spectroscopy of the central binary collected over the ensuing two decades, resulting in the determination that the orbital period is 4.9 days, and that it consists of two nearly identical ∼A1 V stars, each of mass ~ 2.7 $M_\odot$.
The physical parameters of the A stars, combined with evolutionary tracks, show that both are in the short-lived "blue-hook" evolutionary phase that occurs between the main sequence and the Hertzsprung gap, and that the age of the system is about 520 Myr. One puzzle is that the stars' rotational velocities are different from each other, and considerably slower than synchronous with the orbital period. It is possible that the center-of-mass velocity of the eclipsing pair is varying with time, which would suggest that there is an unseen third orbiting body in the system. We propose a scenario in which the system began as a hierarchical triple, consisting of a ~ 2.9 $M_\odot$ star orbited by the close pair of A stars. Upon reaching the AGB stage, the primary engulfed the close pair into a common envelope, leading to a rapid contraction of the orbit and catastrophic ejection of the envelope into the orbital plane. In this picture, the exposed core of the initial primary is now a white dwarf of ~ 0.7 $M_\odot$, orbiting the eclipsing pair, which has already cooled below the detectability possible by *IUE* at our derived distance of 2.3 kpc and a reddening of $E(B-V) = 0.40$. The SuWt 2 system may be destined to perish as a Type Ia supernova.

Accepted for publication in Astronomical Journal
Available from arXiv:1009.1919

Direct detection of a magnetic field in the photosphere of the single M giant EK Boo. How common is magnetic activity among M giants?

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We study the fast rotating M5 giant EK Boo by means of spectropolarimetry to obtain direct and simultaneous measurements of both the magnetic field and activity indicators, in order to infer the origin of the activity in this fairly evolved giant. We used the new spectropolarimeter NARVAL at the Bernard Lyot Telescope (Observatoire du Pic du Midi, France) to obtain a series of Stokes I and Stokes V profiles for EK Boo. Using the Least Square Deconvolution technique we were able to detect the Zeeman signature of the magnetic field. We measured its longitudinal component by means of the averaged Stokes V and Stokes I profiles. The spectra also permitted us to monitor the Ca II K&H chromospheric emission lines, which are well known as indicators of stellar magnetic activity. From ten observations obtained between April 2008 and March 2009, we deduce that EK Boo has a magnetic field, which varied in the range of -0.1 to -8 G. On March 13, 2009, a complex structure of Stokes V was observed, which might indicate a dynamo. We also determined the initial mass and evolutionary stage of EK Boo, based on up-to-date stellar evolution tracks. The initial mass is in the range of 2.0–3.6 $M_\odot$, and EK Boo is either on the asymptotic giant branch (AGB), at the onset of the thermal pulse phase, or at the tip of the first (or red) giant branch (RGB). The fast rotation and activity of EK Boo might be explained by angular momentum dredge-up from the interior, or by the merging of a binary.
In addition, we observed eight other M giants, which are known as X-ray emitters,or to be rotating fast for their class. For one of these, β And, presumably also an AGB star, we have a marginal detection of magnetic field, and a longitudinal component B_l of about 1G was measured. More observations like this will answer the question whether EK Boo is a special case, or whether magnetic activity is, rather, more common among M giants than expected.

Accepted for publication in A&A
Available from arXiv:1009.2001

Physico-chemical spectroscopic mapping of the planetary nebula NGC 40 and the 2D_NEB, a new 2D algorithm to study ionised nebulae

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In this paper we present an analysis of the physical and chemical conditions of the planetary nebula NGC 40 through spatially-resolved spectroscopic maps. We also introduce a new algorithm –2D_NEB– based on the well-established IRAF *nebular* package, which was developed to enable the use of the spectroscopic maps to easily estimate the astrophysical quantities of ionised nebulae. The 2D_NEB was benchmarked, and we clearly show that it works properly, since it compares nicely with the IRAF *nebular* software.
Using this software, we derive the maps of several physical parameters of NGC 40. From these maps, we conclude that T_e[N II] shows only a slight temperature variation from region to region, with its values constrained between ∼8,000 K and ∼9,500 K. Electron densities, on the other hand, have a much more prominent spatial variation, as N_e[S II] values vary from ∼1,000 cm^{-3} to ∼3,000 cm^{-3}. Maps of the chemical abundances also show significant variations. From the big picture of our work, we strongly suggest that analysis with spatial resolution be mandatory for more complete study of the physical and chemical properties of planetary nebulae.

Accepted for publication in MNRAS
Available from arXiv:1009.5876

The Arizona radio observatory 1-mm spectral survey of IRC +10 216 and VY Canis Majoris (215–285 GHz)

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A low noise (1σ rms ∼ 3 mK) 1 mm spectral survey (214.5–285.5 GHz) of the oxygen-rich supergiant VY Canis Majoris and the carbon-rich asymptotic giant branch star IRC +10 216 has been conducted using the Arizona Radio Observatory's 10 m Submillimeter Telescope. Here the complete data set is presented. This study, carried out with a new ALMA-type receiver, marks the first continuous band scan of an O-rich circumstellar envelope, and the most sensitive survey to date of IRC +10 216. In VY CMa, 130 distinct molecular lines were detected, 14 of which cannot be identified; in IRC +10 216, 717 lines were observed, with 126 features remaining unidentified. In the 1 mm bands of VY CMa and IRC +10 216, emission is present from 18 and 32 different chemical compounds, respectively, with 10 species common to both sources. Many narrow emission lines were observed in both circumstellar shells, arising from vibrationally excited molecules and from refractory-containing species. Line profiles in VY CMa also exhibit a variety of different shapes, caused by the complex, asymmetric outflow of this object. The survey highlights the fact that C-rich and O-rich circumstellar envelopes are chemically interesting, and both are sources of new interstellar molecules. The high number of unidentified lines and the unreliable rest frequencies for known species such as NaCN indicate the need for additional laboratory spectroscopy studies.

Published in The Astrophysical Journal Supplement Series
Available from http://iopscience.iop.org/0067-0049/190/2/348

Conference Papers

Criss-cross mapping BD +30 3639: a new kinematic analysis technique

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We present a new analysis of kinematic data of the young planetary nebula BD +30 3639. The data include spectroscopic long-slit and internal proper motion measurements. In this paper we also introduce a new type of mapping of kinematic proper motion data that we name "criss-cross" mapping. It basically consists of finding all points where extended proper motion vectors cross converge. From the crossing points a map is generated which helps to interpret the kinematic data. From the criss-cross mapping of BD +30 3639, we conclude that the kinematic center is $\approx 0.5''$ off-set to the South–East from the central star. The mapping does also show evidence for a non-homologous expansion of the nebula that is consistent with a disturbance aligned with the bipolar molecular bullets.

Oral contribution, published in "Asymmetrical Planetary Nebulae 5", held at Bowness-on-Windermere, UK

Available from arXiv:1008.3894

GASKAP — A Galactic spectral line survey with the Australian Square Kilometre Array Pathfinder

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One of the Survey Science Projects that the Australian Square Kilometre Array Pathfinder (ASKAP) telescope will do in its first few years of operation is a study of the 21-cm line of H I and the 18-cm lines of OH in the Galactic Plane and the Magellanic Clouds and Stream. The wide-field ASKAP can survey a large area with very high sensitivity much faster than a conventional telescope because of its focal plane array of receiver elements. The brightness sensitivity for the widespread spectral line emission of the interstellar medium depends on the beam size and the survey speed. In the GASKAP survey, maps with different resolutions will be synthesized simultaneously; these will be matched to different scientific applications such as diffuse H I and OH emission, OH masers, and H I absorption toward background continuum sources. A great many scientific questions will be answered by the GASKAP survey results; a central topic is the exchange of matter and energy between the Milky Way disk and halo. The survey will show how neutral gas at high altitude (z) above the disk, like the Magellanic Stream, makes its way down through the halo, what changes it experiences along the way, and how much is left behind.

Oral contribution, published in "The Dynamic ISM: A celebration of the Canadian Galactic Plane Survey," ASP Conference Series

Available from arXiv:1008.4640

ASKAP and MeerKAT surveys of the Magellanic Clouds

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The Magellanic Clouds are a stepping stone from the overwhelming detail of the Milky Way in which we are immersed, to the global characteristics of galaxies both in the nearby and distant universe. They are interacting, gas-rich dwarf galaxies of sub-solar metallicity, not unlike the building blocks that assembled the large galaxies that dominate groups and clusters, and representative of the conditions at the height of cosmic star formation. The Square Kilometre Array (SKA) can make huge strides in understanding galactic metabolism and the ecological processes that govern star formation, by observations of the Magellanic Clouds and other, nearby Magellanic-type irregular galaxies. Two programmes with SKA Pathfinders attempt to pave the way: the approved Galactic ASKAP Spectral Line Survey (GASKAP) includes a deep survey in H I and OH of the Magellanic Clouds, whilst MagiKAT is proposed to perform more detailed studies of selected regions within the Magellanic Clouds — also including Faraday rotation measurements and observations at higher frequencies. These surveys also close the gap with the revolutionizing surveys at far-IR wavelengths with the *Spitzer* Space Telescope and *Herschel* Space Observatory.

Poster contribution, published in "A New Golden Age in Astronomy", ISKAF 2010 Science Meeting, Proceedings of Science
Available from arXiv:1009.0717

Complete calculation of evaluated Maxwellian-averaged cross sections and their uncertainties for s-process nucleosynthesis

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Present contribution represents a significant improvement of our previous calculation of Maxwellian-averaged cross sections and astrophysical reaction rates. Addition of newly-evaluated neutron reaction libraries, such as ROSFOND and Low-Fidelity Covariance Project, and improvements in data processing techniques allowed us to extend it for entire range of s-process nuclei, calculate Maxwellian-averaged cross section uncertainties for the first time, and provide additional insights on all currently available neutron-induced reaction data. Nuclear reaction calculations using ENDF libraries and current Java technologies will be discussed and new results will be presented.

Poster contribution, published in "11$^{\rm th}$ Symposium on Nuclei in the Cosmos, NIC XI"
Available from arXiv:1008.4772
and from Brookhaven National Laboratory Report BNL-93963-2010-CP

Abell 41: nebular shaping by a binary central star?

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We present the first detailed spatio-kinematical analysis and modelling of the planetary nebula Abell 41, which is

known to contain the well-studied close-binary system MT Ser. This object represents an important test case in the study of the evolution of planetary nebulae with binary central stars as current evolutionary theories predict that the binary plane should be aligned perpendicular to the symmetry axis of the nebula.
Longslit observations of the [N II] emission from Abell 41 were obtained using the Manchester Echelle Spectrometer on the 2.1-m San Pedro Mártir Telescope. These spectra, combined with deep, narrowband imagery acquired using ACAM on the William Herschel Telescope, were used to develop a spatio-kinematical model of [N II] emission from Abell 41. The best fitting model reveals Abell 41 to have a waisted, bipolar structure with an expansion velocity of ~ 40 km s^{-1} at the waist. The symmetry axis of the model nebula is within 5° of perpendicular to the orbital plane of the central binary system. This provides strong evidence that the close-binary system, MT Ser, has directly affected the shaping of its host nebula, Abell 41.

Oral contribution, published in "Asymmetric Planetary Nebulae 5"
Available from arXiv:1009.1805

Proto-Planetary Nebulae with the *Spitzer* Space Telescope

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The transition from Asymptotic Giant Branch star to Planetary Nebula is short-lived and mysterious. Though it lasts only a few thousand years, it is thought to be the time when the asymmetries observed in subsequent phases arise. During this epoch, the star is shrouded in thick clouds of dust and molecular gas; infrared observations are needed to reveal these objects at their most pivotal moment. I present preliminary results of a *Spitzer* study of targets spanning the range from post-AGB stars to Planetary Nebulae with the goal of determining the genesis of asymmetry in these objects.

Oral contribution, published in "Asymmetric Planetary Nebulae V"

Prediction of close binarity based on planetary nebula morphology

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A thorough search of the OGLE-III microlensing project has more than doubled the total sample of PNe known to have close binary central stars. These discoveries have enabled close binary induced morphological trends to be revealed for the first time. Canonical bipolar nebulae, low-ionisation structures and polar outflows are all identified within the sample and are provisionally associated with binarity. We have embarked upon a large photometric monitoring program using the Flemish Mercator telescope to simultaneously test the predictive power of these morphological features and to find more close binaries. Early results are very positive with at least five binaries found so far. This suggests our method is an effective means to expedite the construction of a statistically significant sample of close

binary shaped nebulae. Such an authoritative sample will be essential to quantify the degree to which close binary nuclei may shape PNe.

Oral contribution, published in "Asymmetric Planetary Nebulae V (APNV)"
Available from arXiv:1009.2890

The binary central stars of PNe with the shortest orbital periods

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Close binarity can play a significant role in the shaping of planetary nebulae (PNe) as the system evolves through the common-envelope phase. We present the detection of two of the shortest orbital periods among PN binary central stars. These are Hen 2-428, a bipolar PN, and V458 Vul, a recent nova surrounded by a mildly bipolar planetary nebula. The properties of the central stars of these systems, of their nebulae and their possible fate are discussed.

Oral contribution, published in "Asymmetric Planetary Nebulae V"
Available from arXiv:1009.3055

Iron depletion into dust grains in Galactic Planetary Nebulae

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We present preliminary results of an analysis of the iron depletion factor into dust grains for a sample of 20 planetary nebulae (PNe) from the Galactic bulge. We compare these results with the ones we obtained in a prior analysis of 28 Galactic disk PNe and 8 Galactic H II regions. We derive high depletion factors in all the objects, suggesting that more than 80% of their iron atoms are condensed into dust grains. The range of iron depletions in the sample PNe covers about two orders of magnitude, and we explore here if the differences are related to the PN morphology. However, we do not find any significant correlation.

Oral contribution, published in "Asymmetric Planetary Nebulae V", eds. A.A. Zijlstra et al., editorial: Ebrary
Available from arXiv:1009.3945

Detailed chemical abundances of globular clusters in Local Group dwarf galaxies

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We present detailed chemical abundances of Fe, Ca and Ba for 17 globular clusters (GCs) in 5 Local Group dwarf galaxies: NGC 205, NGC 6822, WLM, the SMC and LMC. These abundances are part of a larger sample of over 20

individual elements measured in GCs in these galaxies using a new analysis method for high resolution, integrated light spectra. Our analysis also provides age and stellar population constraints. The existence of GCs in dwarf galaxies with a range of ages implies that there were episodes of rapid star formation throughout the history of these galaxies; the abundance ratios of these clusters suggest that the duration of these burst varied considerably from galaxy to galaxy. We find evolution of Fe, Ca, and Ba with age in the LMC, SMC, and NGC 6822 that is consistent with extended, lower-efficiency SF between bursts, with an increasing contribution of low-metallicity AGB ejecta at late times. Our sample of GCs in NGC 205 and WLM are predominantly old and metal-poor with high [Ca/Fe] ratios, implying that the early history of these galaxies was marked by consistently high SF rates.

Poster contribution, published in "A Universe of Dwarf Galaxies", Lyon, June 14–18, 2010
Available from arXiv:1009.4195

Prospects for asymmetric PNe with ALMA

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Millimeter and sub-millimeter observations have made fundamental contributions to our current understanding of the transition from AGB stars to white dwarfs. The approaching era of ALMA brings significantly enhanced observing capabilities at these wavelengths and promises to push back the frontiers in a number of ways. We examine the scientific prospects of this new era for PNe, with an emphasis on how developments may contribute to the goals of the asymmetric PNe community.

Oral contribution, published in "Asymmetric Planetary Nebulae V", eds. A.A. Zijlstra et al.
Available from arXiv:1009.2514

Magnetic fields around (post-)AGB and (Pre-)Planetary Nebuale

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Observational evidence for strong magnetic fields throughout the envelopes of evolved stars is increasing. Many of the instruments coming on line in the near-future will be able to make further contributions to this field. Specifically, maser polarization observations and dust/line polarization in the sub-mm regime has the potential to finally provide a definite picture of the magnetic field strength and configuration from the Asymptotic Giant Branch (AGB) all the way to the Planetary Nebula phase. While current observations are limited in sample size, strong magnetic fields appear ubiquitous at all stages of (post-)AGB evolution. Recent observations also strongly support a field structure that is maintained from close to the star to several thousands of AU distance. While its origin is still unclear, the magnetic field is thus a strong candidate for shaping the stellar outflows on the path to the planetary nebula phase and might even play a role in determining the stellar mass-loss.

Oral contribution, published in "Asymmetric Planetary Nebulae V"
Available from arXiv:1009.4067

Imaging Planetary Nebulae with *Herschel*-PACS and SPIRE

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In this paper we will discuss the images of Planetary Nebulae that have recently been obtained with PACS and SPIRE on board the *Herschel* satellite. This comprises results for NGC 650 (the little Dumbbell nebula), NGC 6853 (the Dumbbell nebula), and NGC 7293 (the Helix nebula).

Oral contribution, published in "Asymmetrical Planetary Nebulae 5"
Available from arXiv:1009.5258