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. 196 — 2 November 2013

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

Editors: Jacco van Loon and Albert Zijlstra

Editorial

Dear Colleagues,

It is a pleasure to present you the 196th issue of the AGB Newsletter.

VY Canis Majoris is "star of the month" (Kamiński et al.; Alcolea et al.; Matsuura et al.), with NN Serpentis a good second along with other works on post-main sequence survival of planets (Veras et al.; Adams & Bloch; Mustill et al.; Marsh et al.). Furthermore in this edition: beautiful interferometric observations of the dust formation sequence (Karovicova et al.), brave work on Super-AGB stars (Doherty et al.), post-AGB stars explain LINER galaxies (Singh et al.), and important AAVSO results on amplitude variations in red giants and red supergiants (Percy & Abachi; Percy & Khatu). The Boomerang Nebula: the coldest place in the Universe? Well, that is, if we ignore low-temperature laboratory experiments on Earth!

Don't ignore the conference proceedings papers either. Sometimes, the most interesting ideas are found there. Whilst even better ideas are still out there to be had.

The next issue is planned to be distributed around the 1st of December.

Editorially Yours,
Jacco van Loon and Albert Zijlstra

Food for Thought

This month's thought-provoking statement is:

There exist stars larger than VY Canis Majoris

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

An interferometric spectral-line and imaging survey of VY Canis Majoris in the 345 GHz band

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A spectral line survey of the oxygen-rich red supergiant VY Canis Majoris was made between 279 and 355 GHz with the Submillimeter Array. Two hundred twenty three spectral features from 19 molecules (not counting isotopic species of some of them) were observed, including the rotational spectra of TiO, TiO_2, and AlCl for the first time in this source. The parameters and an atlas of all spectral features is presented. Observations of each line with a synthesized beam of $\sim 0\farcs9$, reveal the complex kinematics and morphology of the nebula surrounding VY CMa. Many of the molecules are observed in high lying rotational levels or in excited vibrational levels. From these, it was established that the main source of the submillimeter-wave continuum (dust) and the high excitation molecular gas (the star) are separated by $\sim 0\farcs15$. Apparent coincidences between the molecular gas observed with the SMA, and some of the arcs and knots observed at infrared wavelengths and in the optical scattered light by the *Hubble* Space Telescope are identified. The observations presented here provide important constraints on the molecular chemistry in oxygen-dominated circumstellar environments and a deeper picture of the complex circumstellar environment of VY CMa.

Accepted for publication in ApJS
Available from arXiv:1309.7360

The molecular envelope of CRL 618: A new model based on *Herschel*/HIFI observations

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Aims: We study the physical properties and molecular excitation of the different warm gas components found in the protoplanetary nebula CRL 618. The proper study of the nebular structure and its implications on the dynamics and kinematics of the molecular gas are of particular importance for understanding the evolution of these objects.
Methods: We revise our previous *Herschel*/HIFI observations, which consist of several ^{12}CO and ^{13}CO lines in the far-infrared/sub-mm band in the nebula CRL 618. These data have been re-analyzed in detail by improving calibration, the signal-to-noise-ratio, and baseline substraction. Due to the high performance of *Herschel*, it was possible to identify the contributions of the different nebular components to the line profiles. Previous optical imaging and mm-wave interferometric mapping revealed that CRL 618 shows a complex molecular structure composed of a large and diffuse spherical halo, a compact central core, double shells, and a fast bipolar outflow. We have used a spatio-kinematical model to better constrain the temperature, density, and kinematics of the molecular components probed by the improved CO observations.
Results: The ^{12}CO and ^{13}CO J = 16–15, J = 10–9, and J = 6–5 transitions are detected in this source. The line profiles present a composite structure showing spectacular wings in some cases, which become dominant as the energy level increases. Our analysis of the high-energy CO emission with the already known low-energy J = 2–1 and J = 1–0 lines confirms that the high-velocity component, or the fast bipolar outflow, is hotter than previously estimated with a typical temperature of $\sim$ 300 K. This very fast component may then be an example of a very recent acceleration of the gas by shocks that has not yet cooled down. We also find that the dense central core is characterized by a very low expansion velocity, $\sim$ 5 km s^{-1}, and a strong velocity gradient. We conclude that this component is very likely to be the unaltered circumstellar layers that are lost in the last AGB phase, where the ejection velocity is particularly

low. The physical properties of the other two nebular components, the diffuse halo and the double empty shell, more or less agrees with the estimations derived in previous models.

Accepted for publication in Astronomy & Astrophysics
Available from arXiv:1309.6206

High-latitude supergiant V5112 Sgr: enrichment of the envelope with heavy s-process metals

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High-resolution ($R = 60\,000$) échelle spectroscopy of the post-AGB supergiant V5112 Sgr performed in 1996–2012 with the 6-meter telescope BTA has revealed peculiarities of the star optical spectrum and has allowed the variability of the velocity field in the stellar atmosphere and envelope to be studied in detail. An asymmetry and splitting of strong absorption lines with a low lower-level excitation potential have been detected for the first time. The effect is maximal in Ba II lines whose profile is split into three components. The profile shape and positions of the split lines change with time. The blue components of the split absorption lines are shown to be formed in a structured circumstellar envelope, suggesting an efficient dredge-up of the heavy metals produced during the preceding evolution of this star into the envelope. The envelope expansion velocities have been estimated to be 20 and 30 km s^{-1}. The mean radial velocity from diffuse bands in the spectrum of V5112 Sgr coincides with that from the short-wavelength shell component of the Na I D-lines, which leads to the conclusion about their formation in the circumstellar envelope. Analysis of the set of radial velocities v_r based on symmetric absorption lines has confirmed the presence of pulsations in the stellar atmosphere with an amplitude 8 km s^{-1}.

Accepted for publication in Astronomy Letters
Available from arXiv:1310.0564

The Great Escape III: Placing post-main-sequence evolution of planetary and binary systems in a Galactic context

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Our improving understanding of the life cycle of planetary systems prompts investigations of the role of the Galactic environment before, during and after Asymptotic Giant Branch (AGB) stellar evolution. Here, we investigate the interplay between stellar mass loss, Galactic tidal perturbations, and stellar flybys for evolving stars which host one planet, smaller body or stellar binary companion and reside in the Milky Way's bulge or disc. We find that the potential evolutionary pathways from a main sequence (MS) to a white dwarf (WD) planetary system are a strong function of Galactocentric distance only with respect to the prevalence of stellar flybys. Planetary ejection and collision with the parent star should be more common towards the bulge. At a given location anywhere in the Galaxy, if the mass loss is adiabatic, then the secondary is likely to avoid close flybys during AGB evolution, and cannot eventually escape the resulting WD because of Galactic tides alone. Partly because AGB mass loss will shrink a planetary system's Hill ellipsoid axes by about 20 to 40 per cent, Oort clouds orbiting WDs are likely to be more depleted and dynamically excited than on the MS.

Accepted for publication in MNRAS
Available from arXiv:1310.1395

New insights into the dust formation of oxygen-rich AGB stars

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AGB stars are one of the major sources of dust in the universe. The formation of molecules and dust grains and their subsequent expulsion into the interstellar medium via strong stellar winds is under intense investigation. This is in particular true for oxygen-rich stars, for which the path of dust formation has remained unclear. We conducted spatially and spectrally resolved mid-infrared multi-epoch interferometric observations to investigate the dust formation process in the extended atmospheres of oxygen-rich AGB stars. We observed the Mira variable AGB stars S Ori, GX Mon and R Cnc between February 2006 and March 2009 with the MIDI instrument at the VLT interferometer. We compared the data to radiative transfer models of the dust shells, where the central stellar intensity profiles were described by dust-free dynamic model atmospheres. We used Al_2O_3 and warm silicate grains, following earlier studies in the literature. Our S Ori and R Cnc data could be well described by an Al_2O_3 dust shell alone, and our GX Mon data by a mix of an Al_2O_3 and a silicate shell. The best-fit parameters for S Ori and R Cnc included photospheric angular diameters $\Theta_{\rm Phot}$ of 9.7 ± 1.0 mas and 12.3 ± 1.0 mas, optical depths $\tau_{\rm V}(Al_2O_3)$ of 1.5 ± 0.5 and 1.35 ± 0.2, and inner radii $R_{\rm in}$ of 1.9 ± 0.3 $R_{\rm Phot}$ and 2.2 ± 0.3 $R_{\rm Phot}$, respectively. Best-fit parameters for GX Mon were $\Theta_{\rm Phot} = 8.7 \pm 1.3$ mas, $\tau_{\rm V}(Al_2O_3) = 1.9 \pm 0.6$, $R_{\rm in}(Al_2O_3) = 2.1 \pm 0.3$ $R_{\rm Phot}$, $\tau_{\rm V}(\text{silicate}) = 3.2 \pm 0.5$, and $R_{\rm in}(\text{silicate}) = 4.6 \pm 0.2$ $R_{\rm Phot}$. Our data did not show evidence of intra-cycle and cycle-to-cycle variability or of asymmetries within the error-bars and within the limits of our baseline and phase coverage. Our model fits constrain the chemical composition and the inner boundary radii of the dust shells, as well as the photospheric angular diameters. Our interferometric results are consistent with Al_2O_3 grains condensing close to the stellar surface at about 2 stellar radii, co-located with the extended atmosphere and SiO maser emission, and warm silicate grains at larger distances of about 4–5 stellar radii. We verified that the number densities of aluminum can match that of the best-fit Al_2O_3 dust shell near the inner dust radius in sufficiently extended atmospheres, confirming that Al_2O_3 grains can be seed particles for the further dust condensation. Together with literature data of the mass-loss rates, our sample is consistent with a hypothesis that stars with low mass-loss rates form primarily dust that preserves the spectral properties of Al_2O_3, and stars with higher mass-loss rate form dust with properties of warm silicates.

Accepted for publication in A&A
Available from arXiv:1310.1924

Sensitive CO and ^{13}CO survey of water fountain stars. Detections towards IRAS 18460−0151 and IRAS 18596+0315

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Water fountain stars represent a stage between the asymptotic giant branch (AGB) and planetary nebulæ phases, when the mass loss changes from spherical to bipolar. These types of evolved objects are characterized by high-velocity jets in the 22 GHz water maser emission. We surveyed the CO and ^{13}CO line emission towards a sample of ten water fountain stars through observing the J = 1–0 and 2–1 lines of CO and ^{13}CO, using the 30m IRAM radio telescope at Pico Veleta. All the water fountains visible from the observatory were surveyed. Most of the line emission arises from foreground or background Galactic clouds, and we had to thoroughly analyse the spectra to unveil the velocity components related to the stars. In two sources, IRAS 18460−0151 and IRAS 18596+0315, we identified wide velocity components with a width of 35–40 km s^{-1} that are centred at the stellar velocities. These wide components can be associated with the former AGB envelope of the progenitor star. A third case, IRAS 18286−0959, is reported as tentative; in this case a pair of narrow velocity components, symmetrically located with respect to the stellar velocity, has been discovered. We also modelled the line emission using an LVG code and derived some global physical parameters, which allowed us to discuss the possible origin of this gas in relation to the known bipolar outflows. For IRAS 18460−0151 and IRAS 18596+0315, we derived molecular masses close to 0.2 $M_\odot$, mean densities of 10^4 cm^{-3}, and mass-loss rates of 10^{-4} $M_\odot$ yr^{-1}. The kinetic temperatures are rather low, between 10 and 50 K in both cases, which suggests that the CO emission is arising from the outer and cooler regions of the envelopes. No fitting was possible for IRAS 18286−0959, because line contamination can not be discarded in this case.

Accepted for publication in Astronomy and Astrophysics
Available from arXiv:1310.2615

HIFISTARS *Herschel*/HIFI observations of VY Canis Majoris. Molecular-line inventory of the envelope around the largest known star

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The study of the molecular gas in the circumstellar envelopes of evolved stars is normally undertaken by observing lines of CO (and other species) in the millimetre-wave domain. In general, the excitation requirements of the observed lines are low at these wavelengths, and therefore these observations predominantly probe the cold outer envelope while studying the warm inner regions of the envelopes normally requires sub-millimetre (sub-mm) and far-infrared (FIR) observational data.
To gain insight into the physical conditions and kinematics of the warm (100–1000 K) gas around the red hyper-giant VY CMa, we performed sensitive high spectral resolution observations of molecular lines in the sub-mm/FIR using the HIFI instrument of the *Herschel* Space Observatory. We observed CO, H_2O, and other molecular species, sampling excitation energies from a few tens to a few thousand K. These observations are part of the *Herschel* Guaranteed Time Key Program HIFISTARS.
We detected the $J = 6$–5, $J = 10$–9, and $J = 16$–15 lines of ^{12}CO and ^{13}CO at $\sim$ 100, 300, and 750 K above the ground state (and the ^{13}CO $J = 9$–8 line). These lines are crucial for improving the modelling of the internal layers of the envelope around VY CMa. We also detected 27 lines of H_2O and its isotopomers, and 96 lines of species such as NH_3, SiO, SO, SO_2, HCN, OH and others, some of them originating from vibrationally excited levels. Three lines were not unambiguously assigned.
Our observations confirm that VY CMa's envelope must consist of two or more detached components. The molecular excitation in the outer layers is significantly lower than in the inner ones, resulting in strong self-absorbed profiles in molecular lines that are optically thick in this outer envelope, for instance, low-lying lines of H_2O. Except for the most abundant species, CO and H_2O, most of the molecular emission detected at these sub-mm/FIR wavelengths arise from

the central parts of the envelope.
The spectrum of VY CMa is very prominent in vibrationally excited lines, which are caused by the strong IR pumping present in the central regions. Compared with envelopes of other massive evolved stars, VY CMa's emission is particularly strong in these vibrationally excited lines, as well as in the emission from less abundant species such as $H^{13}CN$, SO, and NH_3.

Accepted for publication in Astronomy and Astrophysics
Available from arXiv:1310.2400

A nova re-accretion model for J-type carbon stars

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The J-type carbon (J)-stars constitute 10–15% of the observed carbon stars in both our Galaxy and the Large Magellanic Cloud (LMC). They are characterized by strong ^{13}C absorption bands with low $^{12}C/^{13}C$ ratios along with other chemical signatures peculiar for typical carbon stars, e.g., a lack of s-process enhancement. Most of the J-stars are dimmer than the N-type carbon stars some of which, by hot-bottom burning, make ^{13}C only in a narrow range of masses. We investigate a binary-star formation channel for J-stars involving re-accretion of carbon-rich nova ejecta on main-sequence companions to low-mass carbon-oxygen white-dwarfs. The subsequent evolution of the companion stars in such systems is studied with a rapid binary evolutionary code to predict chemical signatures of nova pollution in systems which merge into giant single stars. A detailed population synthesis study is performed to estimate the number of these mergers and compare their properties with observed J-stars. Our results predict that such nova polluted mergers evolve with low luminosities as well as low $^{12}C/^{13}C$ ratios like the majority of observed J-stars (e.g., in the LMC) but cannot account for the observed fraction of J-stars in existing surveys of carbon stars.

Accepted for publication in Astronomy and Astrophysics
Available from arXiv:1310.1402
and from http://www.astro.uni-bonn.de/∼sutirtha

Super and massive AGB Stars: II – Nucleosynthesis and yields – $Z = 0.02$, 0.008 and 0.004

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We have computed detailed evolution and nucleosynthesis models for super and massive AGB stars over the mass range 6.5–9.0 $M_{\odot}$ in divisions of 0.5 $M_{\odot}$ with metallicities $Z = 0.02$, 0.008 and 0.004. These calculations, in which we find third dredge-up and hot bottom burning, fill the gap between existing low and intermediate-mass AGB star models and high mass star models that become supernovæ. For the considered metallicities, the composition of the yields is largely dominated by the thermodynamic conditions at the base of the convective envelope rather than by the pollution arising from third dredge up. We investigate the effects of various uncertainties, related to the mass-loss rate, mixing length parameter, and the treatment of evolution after the envelope instability that develops near the end of the (Super)AGB phase. Varying these parameters alter the yields mainly because of their impact on the amount of third dredge up enrichment, and to a lesser extent on the hot bottom burning conditions. Our models produce significant amounts of ^{4}He, ^{7}Li (depending on the mass-loss formulation) ^{13}C, ^{14}N, ^{17}O, ^{23}Na, ^{25}Mg, as well the radioactive isotope ^{26}Al in agreement with previous investigation. In addition our results show enrichment of ^{22}Ne, ^{26}Mg and ^{60}Fe, as well as a substantial increase in our proxy neutron capture species representing all species heavier than iron. These stars may provide important contributions to the Galaxy's inventory of the heavier Mg isotopes,

^{14}N, ^{7}Li and ^{27}Al.

Accepted for publication in MNRAS
Available from arXiv:1310.2614
and from http://users.monash.edu/~cdoherty/

Evolution of planetary orbits with stellar mass loss and tidal dissipation

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Intermediate mass stars and stellar remnants often host planets, and these dynamical systems evolve because of mass loss and tides. This paper considers the combined action of stellar mass loss and tidal dissipation on planetary orbits in order to determine the conditions required for planetary survival. Stellar mass loss is included using a so-called Jeans model, described by a dimensionless mass loss rate γ and an index β. We use an analogous prescription to model tidal effects, described here by a dimensionless dissipation rate Γ and two indices (q, p). The initial conditions are determined by the starting value of angular momentum parameter η_0 (equivalently, the initial eccentricity) and the phase θ of the orbit. Within the context of this model, we derive an analytic formula for the critical dissipation rate Γ, which marks the boundary between orbits that spiral outward due to stellar mass loss and those that spiral inward due to tidal dissipation. This analytic result $\Gamma = \Gamma(\gamma, \beta, q, p, \eta_0, \theta)$ is essentially exact for initially circular orbits and holds to within an accuracy of $\approx 50\%$ over the entire multi-dimensional parameter space, where the individual parameters vary by several orders of magnitude. For stars that experience mass loss, the stellar radius often displays quasi-periodic variations, which produce corresponding variations in tidal forcing; we generalize the calculation to include such pulsations using a semi-analytic treatment that holds to the same accuracy as the non-pulsating case. These results can be used in many applications, e.g., to predict/constrain properties of planetary systems orbiting white dwarfs.

Accepted for publication in ApJ Letters
Available from arXiv:1310.2577

Long-term evolution of three-planet systems to the post-Main Sequence and beyond

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We study the stability of systems of three giant planets orbiting 3–8 $M_\odot$ stars at orbital distances of > 10 au as the host star ages through the Main Sequence (MS) and well into the White Dwarf (WD) stage. Systems are stable on the MS if the planets are separated by more than ~ 9 Hill radii. Most systems surviving the MS will remain stable until the WD phase, although planets scattered onto small pericentres in unstable systems can be swallowed by the expanding stellar envelope when the star ascends the giant branches. Mass loss at the end of the asymptotic giant branch triggers delayed instability in many systems, leading to instabilities typically occurring at WD cooling ages of a few 100 Myr. This instability occurs both in systems that survived the star's previous evolution unscathed, and in systems that previously underwent scattering instabilities. The outcome of such instability around WDs is overwhelmingly the ejection of one of the planets from the system, with several times more ejections occurring during the WD phase than during the MS. Furthermore, few planets are scattered close to the WD, just outside the Roche limit, where they can be tidally circularised. Hence, we predict that planets in WD systems rarely dynamically evolve to become "hot Jupiters". Nor does it appear that the observed frequency of metal pollution in WD atmospheres

can be entirely explained by planetesimals being destabilised following instability in systems of multiple giant planets, although further work incorporating low-mass planets and planetesimals is needed.

Accepted for publication in MNRAS
Available from arXiv:1310.3168

Main-sequence progenitor configurations of the NN Ser candidate circumbinary planetary system are dynamically unstable

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Recent observations of the NN Serpentis post-common envelope binary system have revealed eclipse timing variations that have been attributed to the presence of two Jovian-mass exoplanets. Under the assumption that these planets are real and survived from the binary's Main Sequence state, we reconstruct initial binaries that give rise to the present NN Ser configuration and test the dynamical stability of the original system. Under standard assumptions about binary evolution, we find that survival of the planets through the entire Main Sequence life-time is very unlikely. Hence, we conclude that the planets are not survivors from before the Common Envelope phase, implying that either they formed recently out of material ejected from the primary, or that the observed signals are of non-planetary origin.

Accepted for publication in MNRAS
Available from arXiv:1309.3881

Chemical abundances in the extremely carbon and xenon-rich Halo planetary nebula H 4-1

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We performed detailed chemical abundance analysis of the extremely metal-poor ([Ar/H]~ -2) Halo planetary nebula H 4-1 based on the multi-wavelength spectra from Subaru/HDS, GALEX, SDSS, and *Spitzer*/IRS and determined the abundances of 10 elements. The C and O abundances were derived from collisionally excited lines (CELs) and are almost consistent with abundances from recombination lines (RLs). We demonstrated that the large discrepancy in the C abundance between CEL and RL in H 4-1 can be solved using the temperature fluctuation model. We reported the first detection of the [Xe III] 5846 Å line in H 4-1 and determination of its elemental abundance ([Xe/H]$> +0.48$). H 4-1 is the most Xe-rich PN among the Xe-detected PNe. The observed abundances are close to the theoretical prediction by a ~ 2.0 $M_\odot$ single star model with initially r-process element rich ([r/Fe]$= +2.0$ dex). The observed Xe abundance would be a product of the r-process in primordial SNe. The [C/O] vs. [Ba/(Eu or Xe)] diagram suggests that the progenitor of H 4-1 shares the evolution with two types of carbon-enhanced metal-poor stars (CEMP), CEMP-r/s and CEMP-*no* stars. The progenitor of H 4-1 is a presumably binary formed in an r-process rich environment.

Accepted for publication in The Astrophysical Journal
Available from arXiv:1310.1151

Period–luminosity relations in evolved red giants explained by solar-like oscillations

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Solar-like oscillations in red giants have been investigated with the space-borne missions CoRoT and *Kepler*, while pulsations in more evolved M giants have been studied with ground-based microlensing surveys. After 3.1 years of observation with *Kepler*, it is now possible to link these different observations of semi-regular variables.
We aim to identify period–luminosity sequences in evolved red giants identified as semi-regular variables and to interpret them in terms of solar-like oscillations. Then, we investigate the consequences of the comparison of ground-based and space-borne observations.
We first measured global oscillation parameters of evolved red giants observed with *Kepler* with the envelope autocorrelation function method. We then used an extended form of the universal red giant oscillation pattern, extrapolated to very low frequency, to fully identify their oscillations. The comparison with ground-based results was then used to express the period–luminosity relation as a relation between the large frequency separation and the stellar luminosity.
From the link between red giant oscillations observed by *Kepler* and period–luminosity sequences, we have identified these relations in evolved red giants as radial and non-radial solar-like oscillations. We were able to expand scaling relations at very low frequency (periods as long as 100 days and large frequency separation less than 50 nHz). This helped us identify the different sequences of period–luminosity relations, and allowed us to propose a calibration of the K magnitude with the observed large frequency separation.
Interpreting period–luminosity relations in red giants in terms of solar-like oscillations allows us to investigate the time series obtained from ground-based microlensing surveys with a firm physical basis. This can be done with an analytical expression that describes the low-frequency oscillation spectra. The different behavior of oscillations at low frequency, with frequency separations scaling only approximately with the square root of the mean stellar density, can be used to precisely address the physics of the semi-regular variables. This will allow improved distance measurements and opens the way to extragalactic asteroseismology with the observations of M giants in the Magellanic Clouds.

Accepted for publication in A&A
Available from arXiv:1310.0839

Rapid dust formation in novæ: The speed class – formation timescale correlation explained

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Observations show that the time of onset of dust formation in classical novæ depends strongly on their speed class, with dust typically taking longer to form in slower novae. Using empirical relationships between speed class, luminosity and ejection velocity, it can be shown that dust formation timescale is expected to be essentially independent of speed class. However, following a nova outburst the spectrum of the central hot source evolves, with an increasing proportion of the radiation being emitted short-ward of the Lyman limit. The rate at which the spectrum evolves also depends on the speed class. We have therefore refined the simple model by assuming photons at energies higher than the Lyman limit are absorbed by neutral hydrogen gas internal to the dust formation sites, therefore preventing these photons reaching the nucleation sites. With this refinement the dust formation timescale is theoretically dependent on speed class and the results of our theoretical modification agree well with the observational data. We consider two types of carbon-based dust, graphite and amorphous carbon, with both types producing similar relationships. Our results can be used to predict when dust will form in a nova of a given speed class and hence when observations should optimally be taken to detect the onset of dust formation.

Accepted for publication in Astrophysical Journal
Available from arXiv:1310.0949

The planets around NN Ser: still there

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We present 25 new eclipse times of the white dwarf binary NN Ser taken with the high-speed camera ULTRACAM on the WHT and NTT, the RISE camera on the Liverpool Telescope, and HAWK-I on the VLT to test the two-planet model proposed to explain variations in its eclipse times measured over the last 25 years. The planetary model survives the test with flying colours, correctly predicting a progressive lag in eclipse times of 36 seconds that has set in since 2010 compared to the previous 8 years of precise times. Allowing both orbits to be eccentric, we find orbital periods of 7.9 ± 0.5 yr and 15.3 ± 0.3 yr, and masses of 2.3 ± 0.5 M_J and 7.3 ± 0.3 M_J. We also find dynamically long-lived orbits consistent with the data, associated with 2:1 and 5:2 period ratios. The data scatter by 0.07 seconds relative to the best-fit model, by some margin the most precise of any of the proposed eclipsing compact object planet hosts. Despite the high precision, degeneracy in the orbit fits prevents a significant measurement of a period change of the binary and of N-body effects. Finally, we point out a major flaw with a previous dynamical stability analysis of NN Ser, and by extension, with a number of analyses of similar systems.

Accepted for publication in MNRAS
Available from arXiv:1310.1391

Herschel SPIRE and PACS observations of the red supergiant VY CMa: analysis of the molecular line spectra

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We present an analysis of the far-infrared and submillimetre molecular emission line spectrum of the luminous M-supergiant VY CMa, observed with the SPIRE and PACS spectrometers aboard the *Herschel* Space Observatory. Over 260 emission lines were detected in the 190–650-μm SPIRE FTS spectra, with one-third of the observed lines being attributable to H_2O. Other detected species include CO, ^{13}CO, $H_2^{18}O$, SiO, HCN, SO, SO_2, CS, H_2S, and NH_3. Our model fits to the observed ^{12}CO and ^{13}CO line intensities yield a $^{12}C/^{13}C$ ratio of 5.6 ± 1.8, consistent with measurements of this ratio for other M supergiants, but significantly lower than previously estimated for VY CMa from observations of lower-J lines. The spectral line energy distribution for twenty SiO rotational lines shows two temperature components: a hot component at ~ 1000 K, which we attribute to the stellar atmosphere and inner wind, plus a cooler ~ 200 K component, which we attribute to an origin in the outer circumstellar envelope. We fit the line fluxes of ^{12}CO, ^{13}CO, H_2O and SiO, using the SMMOL non-LTE line transfer code, with a mass-loss rate of 1.85×10^{-4} $M_\odot$ yr^{-1} between 9 $R_\star$ and 350 $R_\star$. To fit the observed line fluxes of ^{12}CO, ^{13}CO, H_2O and SiO with SMMOL non-LTE line radiative transfer code, along with a mass-loss rate of 1.85×10^{-4} $M_\odot$ yr^{-1}.
To fit the high rotational lines of CO and H_2O, the model required a rather flat temperature distribution inside the dust condensation radius, attributed to the high H_2O opacity. Beyond the dust condensation radius the gas temperature is

fitted best by an $r^{-0.5}$ radial dependence, consistent with the coolant lines becoming optically thin. Our H_2O emission line fits are consistent with an ortho:para ratio of 3 in the outflow.

Accepted for publication in MNRAS
Available from arXiv:1310.2947

Amplitude variations in pulsating red giants

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We have used long-term AAVSO visual observations and Fourier and wavelet analysis to study the long-term amplitude variations in 29 single-mode and 30 double-mode semiregular (SR) pulsating red giants, in the "long secondary periods" (LSPs) of 26 SR stars, and in 10 Mira stars. The amplitudes of the single-mode SR stars vary by factors of 2 to over 10, on time scales of 18 to 170 (median 44) pulsation periods. The amplitudes of the individual modes in double-mode SR stars behave similarly; the median time scale is 31 pulsation periods, with half lying between 24 and 42. The amplitudes of the two modes seem to vary independently, rather than varying in phase or antiphase. The amplitudes of the Mira stars vary by typically factors of 1.1 to 1.3, on time scales of about 35 pulsation periods. The amplitudes of the LSPs, in most stars, vary by up to a factor of 2, on time scales of about 30 LSPs or greater. In view of the uncertainty in determining the time scales, we conclude that the time scales of the amplitude variations are similar in each of these four samples. These results should assist theorists in understanding the nature and cause of the amplitudes and their variations.

Accepted for publication in Journal of the American Association of Variable Star Observers
Available from http://www.aavso.org/sites/default/files/jaavso/ej243.pdf

The nature of LINER galaxies: Ubiquitous hot old stars and rare accreting black holes

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Galaxies, which often contain ionised gas, sometimes also exhibit a so-called low-ionisation nuclear emission line region (LINER). For 30 years, this was attributed to a central mass-accreting supermassive black hole (more commonly known as active galactic nucleus, AGN) of low luminosity, making LINER galaxies the largest AGN sub-population, which dominate in numbers over higher luminosity Seyfert galaxies and quasars. This, however, poses a serious problem. While the inferred energy balance is plausible, many LINERs clearly do not contain any other independent signatures of an AGN. Using integral field spectroscopic data from the CALIFA survey, we compare the observed radial surface brightness profiles with what is expected from illumination by an AGN. Essential for this analysis is a proper extraction of emission lines, especially weak lines, such as Balmer Hα lines, which are superposed on an absorption trough. To accomplish this, we use the GANDALF code, which simultaneously fits the underlying stellar continuum and emission lines. For 48 galaxies with LINER-like emission, we show that the radial emission-line surface brightness profiles are inconsistent with ionisation by a central point-source and hence cannot be due to an AGN alone. The most probable explanation for the excess LINER-like emission is ionisation by evolved stars during the short but very hot and energetic phase known as post-AGB. This leads us to an entirely new interpretation. Post-AGB stars are ubiquitous and their ionising effect should be potentially observable in every galaxy with the gas present and with stars older than $\sim$ 1 Gyr unless a stronger radiation field from young hot stars or an AGN outshines them. This means that galaxies with LINER-like emission are not a class defined by a property but rather by the absence of a property. It also explains why LINER emission is observed mostly in massive galaxies with old stars and little star formation.

Published in A&A, 558, A43 (2013)
Available from arXiv:1308.4271
and from http://www.aanda.org/articles/aa/abs/2013/10/aa22062-13/aa22062-13.html

Amplitude variations in pulsating red supergiants

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We have used long-term AAVSO visual observations and Fourier and wavelet analysis to identify periods and study long-term amplitude variations in 44 red supergiants. Of these, 12 stars had data which were too sparse and/or had low amplitude and/or were without conspicuous peaks in the Fourier spectrum; 6 stars had only long (2500–4000 days) periods without significant amplitude variation. The other 26 stars had one or two periods, either ”short” (hundreds of days) or ”long” (thousands of days), whose amplitudes varied by up to a factor of 8, but more typically 2–4. The median timescale of the amplitude variation was 18 periods. We interpret the shorter periods as due to pulsation, and the longer periods as analogous to the ”long secondary periods” found in pulsating red giants.

Submitted to JAAVSO
Available from arXiv:1310.6306

ALMA observations of the coldest place in the Universe: The Boomerang Nebula

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The Boomerang Nebula is the coldest known object in the universe, and an extreme member of the class of preplanetary nebulæ, objects which represent a short-lived transitional phase between the asymptotic giant branch and planetary nebula evolutionary stages. Previous single-dish CO (J = 1–0) observations (with a 45$''$ beam) showed that the high-speed outflow in this object has cooled to a temperature significantly below the temperature of the cosmic background radiation. Here we report the first observations of the Boomerang Nebula with ALMA in the CO $J = 2$–1 and $J = 1$–0 lines to resolve the structure of this ultra-cold nebula. We find a central hourglass-shaped nebula surrounded by a patchy, but roughly round, cold high-velocity outflow. We compare the ALMA data with visible-light images obtained with the *Hubble* Space Telescope and confirm that the limb-brightened bipolar lobes seen in these data represent hollow cavities with dense walls of molecular gas and dust producing both the molecular-emission-line and scattered-light structures seen at millimeter and visible wavelengths. The large diffuse biconical shape of the nebula seen in the visible range is likely due to preferential illumination of the cold, high-velocity outflow. We find a compact source of millimeter-wave continuum in the nebular waist – these data, together with sensitive upper limits on the radio continuum using observations with ATCA, indicate the presence of a substantial mass of very large (millimeter-sized) grains in the waist of the nebula. Another unanticipated result is the detection of CO emission regions beyond the ultra-cold region which indicate the re-warming of the cold gas, most likely due to photoelectric grain heating.

Published in Astrophysical Journal
Available from arXiv:1308.4360

Evidence for radiogenic sulfur-32 in Type AB presolar silicon carbide grains?

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We report C, Si, and S isotope measurements on 34 presolar silicon carbide grains of Type AB, characterized by $^{12}C/^{13}C$ < 10. Nitrogen, Mg–Al-, and Ca–Ti-isotopic compositions were measured on a subset of these grains. Three grains show large ^{32}S excesses, a signature that has been previously observed for grains from supernovæ (SNe). Enrichments in ^{32}S may be due to contributions from the Si/S zone and the result of S molecule chemistry in still unmixed SN ejecta or due to incorporation of radioactive ^{32}Si from C-rich explosive He shell ejecta. However, a SN origin remains unlikely for the three AB grains considered here, because of missing evidence for ^{44}Ti, relatively low $^{26}Al/^{27}Al$ ratios (a few times 10^{-3}), and radiogenic ^{32}S along with low $^{12}C/^{13}C$ ratios. Instead, we show that born-again asymptotic giant branch (AGB) stars that have undergone a very-late thermal pulse (VLTP), known to have low $^{12}C/^{13}C$ ratios and enhanced abundances of the light s-process elements, can produce ^{32}Si, which makes such stars attractive sources for AB grains with ^{32}S excesses. This lends support to the proposal that at least some AB grains originate from born-again AGB stars, although uncertainties in the born-again AGB star models and possible variations of initial S-isotopic compositions in the parent stars of AB grains make it difficult to draw a definitive conclusion.

Published in The Astrophysical Journal Letters
Available from arXiv:1310.0485

Physical properties of fullerene-containing Galactic planetary nebulæ

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We searched the *Spitzer* Space Telescope data archive for Galactic planetary nebulæ (PNe), that show the characteristic

17.4 and 18.9 μm features due to C_{60}, also known as buckminsterfullerene. Out of 338 objects with *Spitzer*/IRS data, we found eleven C_{60}-containing PNe, six of which (Hen 2-68, IC 2501, K 3-62, M 1-6, M 1-9, and SaSt 2-3) are new detections, not known to contain C_{60} prior to this work. The strongest 17.4 and 18.9 μm C_{60} features are seen in Tc 1 and SaSt 2-3, and these two sources also prominently show the C_{60} resonances at 7.0 and 8.5 μm. In the other nine sources, the 7.0 and 8.5 μm features due to C_{60} are much weaker. We analyzed the spectra, along with ancillary data, using the photo-ionization code CLOUDY to establish the atomic line fluxes, and determine the properties of the radiation field, as set by the effective temperature of the central star. In addition, we measured the infrared spectral features due to dust grains. We find that the Polycyclic Aromatic Hydrocarbon (PAH) profile over 6–9 μm in these C_{60}-bearing carbon-rich PNe is of the more chemically-processed class A. The intensity ratio of 3.3 μm to 11.3 μm PAH indicates that the number of C-atoms per PAH in C_{60}-containing PNe is small compared to that in non-C_{60} PNe. The *Spitzer* spectra also show broad dust features around 11 and 30 μm. Analysis of the 30-μm feature shows that it is strongly correlated with the continuum, and we propose that a single carbon-based carrier is responsible for both the continuum and the feature. The strength of the 11-μm feature is correlated to the temperature of the dust, suggesting that it is at least partially due to a solid-state carrier. The chemical abundances of C_{60}-containing PNe can be explained by AGB nucleosynthesis models for initially 1.5–2.5 $M_\odot$ stars with $Z = 0.004$. We plotted the locations of C_{60}-containing PNe on a face-on map of the Milky Way and we found that most of these PNe are outside the solar circle, consistent with low metallicity values. Their metallicity suggests that the progenitors are an older population.

Accepted for publication in MNRAS
Available from arXiv:1310.7711

The polluted atmosphere of the white dwarf NLTT 25792 and the diversity of circumstellar environments

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We present an analysis of X-Shooter spectra of the polluted, hydrogen-rich white dwarf NLTT 25792. The spectra show strong lines of calcium (Ca H&K, near-infrared calcium triplet, and Ca I λ4226) and numerous lines of iron along with magnesium and aluminum lines from which we draw the abundance pattern. Moreover, the photospheric Ca H&K lines are possibly blended with a circumstellar component shifted by -20 km $^{-1}$ relative to the photosphere. A comparison with a sample of four white dwarfs with similar parameters show considerable variations in their abundance patterns, particularly in the calcium to magnesium abundance ratio that varies by a factor of five within this sample. The observed variations, even after accounting for diffusion effects, imply similar variations in the putative accretion source. Also, we find that silicon and sodium are significantly underabundant in the atmosphere of NLTT 25792, a fact that may offer some clues on the nature of the accretion source.

Accepted for publication in The Astrophysical Journal
Available from arXiv:1309.6804

Conference Papers

Deep high spectral resolution spectroscopy and chemical composition of ionized nebulæ

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High spectral resolution spectroscopy has proved to be very useful for the advancement of chemical abundances studies

in photoionized nebulæ, such as H II regions and planetary nebulæ (PNe). Classical analyses make use of the intensity of bright collisionally excited lines (CELs), which have a strong dependence on the electron temperature and density. By using high resolution spectrophotometric data, our group has led the determination of chemical abundances of some heavy element ions, mainly O^{++}, O^{+} and C^{++} from faint recombination lines (RLs), allowing us to deblend them from other nearby emission lines or sky features. The importance of these lines is that their emissivity depends weakly on the temperature and density structure of the gas. The unresolved issue in this field is that recombination lines of heavy element ions give abundances that are about 2–3 times higher than those derived from CELs – in H II regions – for the same ion, and can even be a factor of 70 times higher in some PNe. This uncertainty puts into doubt the validity of face values of metallicity that we use as representative not only for ionized nebulæ in the Local Universe, but also for star-forming dwarf and spiral galaxies at different redshifts. Additionally, high-resolution data can allow us to detect and deblend faint lines of neutron capture element ions in PNe. This information would introduce further restrictions to evolution models of AGBs and would help to quantify the chemical enrichment in s-elements produced by low and intermediate mass stars. The availability of an échelle spectrograph at the E-ELT will be of paramount interest to: (a) extend the studies of heavy element recombination lines to low metallicity objects, (b) to extend abundance determinations of s-elements to planetary nebulæ in the extragalactic domain and to bright Galactic and extragalactic H II regions.

Poster contribution, published in Astronomische Nachrichten, Volume 335
Available from arXiv:1310.3683

Surface magnetism of cool giant and supergiant stars

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The existence of starspots on late-type giant stars in close binary systems, that exhibit rapid rotation due to tidal locking, has been known for more than five decades. Photometric monitoring spanning decades has allowed studying the long-term magnetic activity in these stars revealing complicated activity cycles. The development of observing and analysis techniques that has occurred during the past two decades has also enabled us to study the detailed starspot and magnetic field configurations on these active giants. In the recent years magnetic fields have also been detected on slowly rotating giants and supergiant stars. In this paper I review what is known of the surface magnetism in the cool giant and supergiant stars.

Oral contribution, published in IAU Symposium 302: "Magnetic Fields Throughout Stellar Evolution"
Available from arXiv:1310.3678

Review Paper

Variable stars and Galactic structure

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Variable stars have a unique part to play in Galactic astronomy. Among the most important of these variables are the Cepheids (types I and II), the RR Lyræ and the Miras (O- and C-rich). The current status of the basic calibration of these stars in their roles as distance, structure and population indicators is outlined and some examples of recent applications of these stars to Galactic and extragalactic problems is reviewed. The expected impact of Gaia on this type of work is discussed and the need for complementary ground based observations, particularly large scale near-infrared photometry, is stressed.

Published in IAUS 298 "Setting the scene for Gaia and LAMOST"
Available from arXiv:1310.3928