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. 207 — 1 October 2014

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

Editors: Jacco van Loon, Ambra Nanni and Albert Zijlstra

Editorial

Dear Colleagues,

It is our pleasure to present you the 207$^{\rm th}$ issue of the AGB Newsletter. Good old IRC +10°216 features in three new publications, and debris around white dwarfs in another three. AGB stars are also being used to find out more about other galaxies, from the Magellanic Clouds to Centaurus A.

Looking for a postdoctoral job? There's one on offer at JPL, California.

The next issue is planned to be distributed around the 1$^{\rm st}$ of November.

Editorially Yours,
Jacco van Loon, Ambra Nanni and Albert Zijlstra

Food for Thought

This month's thought-provoking statement is:

Is IRC +10° 216 typical?

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

Refereed Journal Papers

Weak magnetic fields in central stars of planetary nebulæ?

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It is not yet clear whether magnetic fields play an essential role in shaping planetary nebulæ (PNe), or whether stellar rotation alone and/or a close binary companion can account for the variety of the observed nebular morphologies. In a quest for empirical evidence verifying or disproving the role of magnetic fields in shaping PNe, we follow up on previous attempts to measure the magnetic field in a representative sample of PN central stars. We obtained low-resolution polarimetric spectra with FORS 2 at VLT for a sample of twelve bright central stars of PNe with different morphology, including two round nebulæ, seven elliptical nebulæ, and three bipolar nebulæ. Two targets are Wolf–Rayet type central stars. For the majority of the observed central stars, we do not find any significant evidence for the existence of surface magnetic fields. However, our measurements may indicate the presence of weak mean longitudinal magnetic fields of the order of 100 Gauss in the central star of the young elliptical planetary nebula IC 418, as well as in the Wolf–Rayet type central star of the bipolar nebula Hen 2-113 and the weak emission line central star of the elliptical nebula Hen 2-131. A clear detection of a 250 G mean longitudinal field is achieved for the A-type companion of the central star of NGC 1514. Some of the central stars show a moderate night-to-night spectrum variability, which may be the signature of a variable stellar wind and/or rotational modulation due to magnetic features. We conclude that strong magnetic fields of the order of kG are not widespread among PNe central stars. Nevertheless, simple estimates based on a theoretical model of magnetized wind bubbles suggest that even weak magnetic fields below the current detection limit of the order of 100 G may well be sufficient to contribute to the shaping of PNe throughout their evolution.

Accepted for publication in Astronomy and Astrophysics
Available from arXiv:1408.3000

An asymmetric jet launching model for the protoplanetary nebula CRL 618

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We propose an asymmetrical jet ejection mechanism in order to model the mirror symmetry observed in the lobe distribution of some protoplanetary nebulæ (pPNe), such as the pPN CRL 618. 3D hydrodynamical simulations of a precessing jet launched from an orbiting source were carried out including an alternation in the ejections of the two outflow lobes, depending on which side of the precessing accretion disk is hit by the accretion column from a Roche lobe-filling binary companion. Both synthetic optical emission maps and position–velocity (PV) diagrams were obtained from the numerical results with the purpose of carrying out a direct comparison with observations. Depending on the observer's point of view, multipolar morphologies are obtained which exhibit a mirror symmetry at large distances from the central source. The obtained lobe sizes and their spatial distribution are in good agreement with the observed morphology of the pPN CRL 618. We also obtain that the kinematic ages of the fingers are similar to those obtained in the observations.

Accepted for publication in Astrophysical Journal
Available from arXiv:1408.4699

Dust and gas mixtures with multiple grain species – a one-fluid approach

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We derive the single-fluid evolution equations describing a mixture made of a gas phase and an arbitrary number of dust phases, generalising the approach developed in Laibe & Price (2014a). A generalisation for continuous dust distributions as well as analytic approximations for strong drag regimes are also provided. This formalism lays the foundation for numerical simulations of dust populations in a wide range of astrophysical systems while avoiding limitations associated with a multiple-fluid treatment. The usefulness of the formalism is illustrated on a series of analytical problems, namely the dustybox, dustyshock and dustywave problems as well as the radial drift of grains and the streaming instability in protoplanetary discs. We find physical effects specific to the presence of several dust phases and multiple drag timescales, including non-monotonic evolution of the differential velocity between phases and increased efficiency of the linear growth of the streaming instability. Interestingly, it is found that under certain conditions, large grains can migrate outwards in protoplanetary discs. This may explain the presence of small pebbles at several hundreds of astronomical units from their central star.

Accepted for publication in MNRAS
Available from arXiv:1407.3569

Interacting supernovæ from photoionization-confined shells around red supergiant stars

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Betelgeuse, a nearby red supergiant, is a fast-moving star with a powerful stellar wind that drives a bow shock into its surroundings. This picture has been challenged by the discovery of a dense and almost static shell that is three times closer to the star than the bow shock and has been decelerated by some external force. The two physically distinct structures cannot both be formed by the hydrodynamic interaction of the wind with the interstellar medium. Here we report that a model in which Betelgeuse's wind is photoionized by radiation from external sources can explain the static shell without requiring a new understanding of the bow shock. Pressure from the photoionized wind generates a standing shock in the neutral part of the wind and forms an almost static, photoionization-confined shell. Other red supergiants should have much more massive shells than Betelgeuse, because the photoionization-confined shell traps up to 35 per cent of all mass lost during the red supergiant phase, confining this gas close to the star until it explodes. After the supernova explosion, massive shells dramatically affect the supernova light curve, providing a natural explanation for the many supernovae that have signatures of circumstellar interaction.

Published in Nature, 512, 282 (2014)
Available from arXiv:1408.2522
and from http://dx.doi.org/10.1038/nature13522

Detailed modelling of the circumstellar molecular line emission of the S-type AGB star W Aquilæ

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Context: S-type AGB stars have a C/O ratio which suggests that they are transition objects between oxygen-rich M-type stars and carbon-rich C-type stars. As such, their circumstellar compositions of gas and dust are thought to be sensitive to their precise C/O ratio, and it is therefore of particular interest to examine their circumstellar properties.
Aims: We present new *Herschel* HIFI and PACS sub-millimetre and far-infrared line observations of several molecular species towards the S-type AGB star W Aql. We use these observations, which probe a wide range of gas temperatures, to constrain the circumstellar properties of W Aql, including mass-loss rate and molecular abundances.
Methods: We used radiative transfer codes to model the circumstellar dust and molecular line emission to determine circumstellar properties and molecular abundances. We assumed a spherically symmetric envelope formed by a constant mass-loss rate driven by an accelerating wind. Our model includes fully integrated H_2O line cooling as part of the solution of the energy balance.
Results: We detect circumstellar molecular lines from CO, H_2O, SiO, HCN, and, for the first time in an S-type AGB star, NH_3. The radiative transfer calculations result in an estimated mass-loss rate for W Aql of 4.0×10^{-6} $M_\odot$ yr^{-1} based on the ^{12}CO lines. The estimated ^{12}CO/^{13}CO ratio is 29, which is in line with ratios previously derived for S-type AGB stars. We find an H_2O abundance of 1.5×10^{-5}, which is intermediate to the abundances expected for M and C stars, and an ortho/para ratio for H_2O that is consistent with formation at warm temperatures. We find an HCN abundance of 3×10^{-6}, and, although no CN lines are detected using HIFI, we are able to put some constraints on the abundance, 6×10^{-6}, and distribution of CN in W Aql's circumstellar envelope using ground-based data. We find an SiO abundance of 3×10^{-6}, and an NH_3 abundance of 1.7×10^{-5}, confined to a small envelope. If we include uncertainties in the adopted circumstellar model – in the adopted abundance distributions, etc. – the errors in the abundances are of the order of factors of a few. The data also suggest that, in terms of HCN, S-type and M-type AGB stars are similar, and in terms of H_2O, S-type AGB stars are more like C-type than M-type AGB stars. We detect excess blue-shifted emission in several molecular lines, possibly due to an asymmetric outflow.
Conclusions: The estimated abundances of circumstellar HCN, SiO and H_2O place W Aql in between M- and C-type AGB stars, i.e. the abundances are consistent with an S-type classification.

Accepted for publication in Astronomy & Astrophysics
Available from arXiv:1408.1825
and from http://www.aanda.org/index.php?option=com_article&access=doi&doi=10.1051/0004-6361/201322807

The emerging planetary nebula CRL 618 and its unsettled central star(s)

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We report deep long-slit emission-line spectra, the line flux ratios, and Doppler profile shapes of various bright optical lines. The low-ionization lines (primarily [N I], [O I], [S II], and [N II]) originate in shocked knots, as reported by many previous observers. Dust-scattered lines of higher ionization are seen throughout the lobes but do not peak in the knots. Our analysis of these line profiles and the readily discernible stellar continuum shows that (1) the central star is an active symbiotic (whose spectrum resembles the central stars of highly bipolar and young PNe such as M 2-9 and Hen 2-437) whose compact companion shows a WC8-type spectrum, (2) extended nebular lines of [O III] and He I originate in the heavily obscured nuclear H II region, and (3) the Balmer lines observed throughout the lobes are dominated by reflected Hα emission from the symbiotic star. Comparing our line ratios with those observed historically shows that (1) the [O III]/Hβ and He I/Hβ ratios have been steadily rising by large amounts throughout the nebula, (2) the Hα/Hβ ratio is steadily decreasing while Hγ/Hβ remains nearly constant, and (3) the low-ionization line ratios formed in the shocked knots have been in decline in different ways at various locations. We show that the first two of these results might be expected if the symbiotic central star has been active and if its bright Hα line has faded significantly in the past 20 years.

Accepted for publication in ApJ
Available from arXiv:1409.2531

Hot Jupiters and cool stars

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Close-in planets are in jeopardy as their host stars evolve off the main sequence to the subgiant and red giant phases. In this paper, we explore the influences of the stellar mass (in the range 1.5–2 $M_\odot$), mass-loss prescription, planet mass (from Neptune up to 10 Jupiter masses), and eccentricity, on the orbital evolution of planets as their parent stars evolve to become subgiants and red giants. We find that planet engulfment during the Red Giant Branch is not very sensitive to the stellar mass or mass-loss rates adopted in the calculations, but quite sensitive to the planetary mass. The range of initial separations for planet engulfment increases with decreasing mass-loss rates or stellar mass and increasing planetary masses. Regarding the planet's orbital eccentricity, we find that as the star evolves into the red giant phase, stellar tides start to dominate over planetary tides. As a consequence, a transient population of moderately eccentric close-in Jovian planets is created, that otherwise would have been expected to be absent from main sequence stars. We find that very eccentric and distant planets do not experience much eccentricity decay, and that planet engulfment is primarily determined by the pericenter distance and the maximum stellar radius.

Accepted for publication in Astrophysical Journal
Available from arXiv:1407.7879

Small carbon chains in circumstellar envelopes

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Observations of carbon-rich circumstellar envelopes were made using the Phoenix spectrograph on the Gemini South telescope to determine the abundance of small carbon chain molecules. Vibration–rotation lines of the ν_3 antisymmetric stretch of C_3 near 2040 cm^{-1} (4.902 μm) have been used to determine the column density for four carbon-rich circumstellar envelopes: CRL 865, CRL 1922, CRL 2023 and IRC +10°216. We additionally calculate the column density of C_5 for IRC +10°216, and provide an upper limit for 5 more objects. An upper limit estimate for the C_7 column density is also provided for IRC +10°216. A comparison of these column densities suggest a revision to current circumstellar chemical models may be needed.

Published in MNRAS, 444, 3721 (2014)
Available from arXiv:1408.5021
and from http://mnras.oxfordjournals.org/content/444/4/3721.full?keytype=ref&ijkey=1eWNqhTcA8SfoW3

A study of K I 7699Å and related shell lines during the recent eclipse of ϵ Aurigæ

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We report high-resolution ($R = 30\,000$, 45 000 and 75 000) échelle and medium-resolution ($R = 22\,000$ and 10 000) spectroscopic observations of the long-period, eclipsing binary ϵ Aurigæ during the 2009–2011 eclipse. Low-excitation shell lines, viz. the K I line at 7699 Å (with 346 data points), Cr I lines at 5345.807 Å and 5348.326 Å and Fe I line at 5110.435 Å which originated from the disk shaped secondary, Hα and the shell components of the Na I D_1 and D_2 lines show significant variation in their shapes and radial velocities during the eclipse. The equivalent width curve shown by the K I line around the ingress and egress phases indicates that the gas density in the trailing edge is about a factor of two higher than density in the leading edge. Using a geometrical model, in which a homogeneous, cylindrical Keplerian disk eclipses the F0 Ia primary star and the shell absorption lines originate from the gaseous atmosphere around an opaque disk, we fit the equivalent width and the radial velocity curves of the K I line covering the full eclipse. A reasonably good fit can be achieved by a low-mass binary model where the mass of the central star of the disk is 5.4 $M_\odot$ and the mass of the primary is 2.5 $M_\odot$ and a disk size of 8.9 au. The low-mass of the primary, with enhanced s-process elements found by Sadakane et al. (2010), supports that it is a post-AGB F supergiant. For the high-mass binary model, the modelled radial velocity curve deviates significantly from the observations.

Accepted for publication in Monthly Notices of the Royal Astronomical Society
Available from arXiv:1409.5493
and from http://prints.iiap.res.in/handle/2248/6645

The star formation history of the Magellanic Clouds derived from long-period variable star counts

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We present the first reconstruction of the star formation history (SFH) of the Large and Small Magellanic Clouds (LMC and SMC) using Long Period Variable stars. These cool evolved stars reach their peak luminosity in the near-infrared; thus, their K-band magnitudes can be used to derive their birth mass and age, and hence the SFH can be obtained. In the LMC, we found a 10-Gyr old single star formation epoch at a rate of ~ 1.5 $M_\odot$ yr^{-1}, followed by a relatively continuous SFR of ~ 0.2 $M_\odot$ yr^{-1}, globally. In the core of the LMC (LMC bar), a secondary, distinct episode is seen, starting 3 Gyr ago and lasting until ~ 0.5 Gyr ago. In the SMC, two formation epochs are seen, one ~ 6 Gyr ago at a rate of ~ 0.28 $M_\odot$ yr^{-1} and another only ~ 0.7 Gyr ago at a rate of ~ 0.3 $M_\odot$ yr^{-1}. The latter is also discernible in the LMC and may thus be linked to the interaction between the Magellanic Clouds and/or Milky Way, while the formation of the LMC bar may have been an unrelated event. Star formation activity is concentrated in the central parts of the Magellanic Clouds now, and possibly has always been if stellar migration due to dynamical relaxation has been effective. The different initial formation epochs suggest that the LMC and SMC did not form as a pair, but at least the SMC formed in isolation.

Accepted for publication in MNRAS
Available from arXiv:1409.0790

Radiogenic p-isotopes from SNe Ia, nuclear physics uncertainties and Galactic chemical evolution compared with values in primitive meteorites

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We calculate the nucleosynthesis of proton-rich isotopes in multi-dimensional Chandrasekhar-mass models of Type Ia supernovæ with different metallicities. Predictions for the abundances of the radiogenic isotopes ^{92}Nb, ^{97,98}Tc, and ^{146}Sm are given in this framework. The abundance seeds are obtained by calculating s-process nucleosynthesis expected to occur in the material accreted onto a carbon–oxygen white dwarf from a binary companion. We explore a well refined grid of s-seeds at different metallicities and ^{13}C-pocket efficiencies. We make use of a Galactic chemical evolution model to predict the contribution of SNe Ia to the solar system p-nuclei composition measured in pristine meteoritic material. We discuss the sensitivity of our results to nuclear physics uncertainties and we find that they can be crucial to determine the role of SNe Ia in the production of ^{92}Nb and ^{146}Sm.

Accepted for publication in Astrophysical Journal
Available from arXiv:1408.6643

The continued optical to mid-IR evolution of V838 Monocerotis

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The eruptive variable V838 Monocerotis gained notoriety in 2002 when it brightened nine magnitudes in a series of three outbursts and then rapidly evolved into an extremely cool supergiant. We present optical, near-IR, and mid-IR spectroscopic and photometric observations of V838 Monocerotis obtained between 2008 and 2012 at the Apache Point Observatory 3.5m, NASA IRTF 3m, and Gemini South 8m telescopes. We contemporaneously analyze the optical & IR spectroscopic properties of V838 Monocerotis to arrive at a revised spectral type L3 supergiant and effective temperature $T_{\rm eff} \sim 2000$–2200 K. Because there are no existing optical observational data for L supergiants in the optical, we speculate that V838 Monocerotis may represent the prototype for L supergiants in this wavelength regime. We find a low level of Hα emission present in the system, consistent with interaction between V838 Monocerotis and its B3 V binary; however, we cannot rule out a stellar collision as the genesis event, which could result in the observed Hα activity. Based upon a two-component blackbody fit to all wavelengths of our data, we conclude that, as of 2009, a shell of ejecta surrounded V838 Monocerotis at a radius of $R = 263 \pm 10$ au with a temperature of $T = 285 \pm 2$ K. This result is consistent with IR interferometric observations from the same era and predictions from the Lynch et al. model of the expanding system, which provides a simple framework for understanding this complicated system.

Accepted for publication in AJ
Available from arXiv:1409.2513

The ejected mass distribution of type Ia supernovæ: a significant rate of non-Chandrasekhar-mass progenitors

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The ejected mass distribution of type Ia supernovae directly probes progenitor evolutionary history and explosion mechanisms, with implications for their use as cosmological probes. Although the Chandrasekhar mass is a natural mass scale for the explosion of white dwarfs as type Ia supernovæ, models allowing type Ia supernovæ to explode at other masses have attracted much recent attention. Using an empirical relation between the ejected mass and the light curve width, we derive ejected masses $M_{\rm ej}$ and nickel masses $M_{\rm Ni}$ for a sample of 337 type Ia supernovæ with redshifts $z < 0.7$ used in recent cosmological analyses. We use hierarchical Bayesian inference to reconstruct the joint $M_{\rm ej}$–$M_{\rm Ni}$ distribution, accounting for measurement errors. The inferred marginal distribution of $M_{\rm ej}$ has a long tail towards sub-Chandrasekhar masses, but cuts off sharply above 1.4 $M_\odot$. Our results imply that 25%–50% of normal type Ia supernovæ are inconsistent with Chandrasekhar-mass explosions, with almost all of these being sub-Chandrasekhar-mass; super-Chandrasekhar-mass explosions make up no more than 1% of all spectroscopically normal type Ia supernovæ. We interpret the type Ia supernova width–luminosity relation as an underlying relation between $M_{\rm ej}$ and $M_{\rm Ni}$, and show that the inferred relation is not naturally explained by the predictions of any single known explosion mechanism.

Accepted for publication in MNRAS
Available from arXiv:1408.6601

The s-process enrichment of the globular clusters M 4 and M 22

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We investigate the enrichment in elements produced by the slow neutron-capture process (s-process) in the globular

clusters M 4 (NGC 6121) and M 22 (NGC 6656). Stars in M 4 have homogeneous abundances of Fe and neutron-capture elements, but the entire cluster is enhanced in s-process elements (Sr, Y, Ba, Pb) relative to other clusters with a similar metallicity. In M 22, two stellar groups exhibit different abundances of Fe and s-process elements. By subtracting the mean abundances of s-poor from s-rich stars, we derive s-process residuals or empirical s-process distributions for M 4 and M 22. We find that the s-process distribution in M 22 is more weighted toward the heavy s-peak (Ba, La, Ce) and Pb than M 4, which has been enriched mostly with light s-peak elements (Sr, Y, Zr). We construct simple chemical evolution models using yields from massive star models that include rotation, which dramatically increases s-process production at low metallicity. We show that our massive star models with rotation rates of up to 50% of the critical (break-up) velocity and changes to the preferred $^{17}O(\alpha,\gamma)^{21}Ne$ rate produce insufficient heavy s-elements and Pb to match the empirical distributions. For models that incorporate asymptotic giant branch yields, we find that intermediate-mass yields (with a ^{22}Ne neutron source) alone do not reproduce the light-to-heavy s-element ratios for M 4 and M 22, and that a small contribution from models with a ^{13}C pocket is required. With our assumption that ^{13}C pockets form for initial masses below a transition range between 3.0 and 3.5 $M_\odot$, we match the light-to-heavy s-element ratio in the s-process residual of M 22 and predict a minimum enrichment timescale of between 240 and 360 Myr. Our predicted value is consistent with the 300 Myr upper limit age difference between the two groups derived from isochrone fitting.

Accepted for publication in Astrophysical Journal
Available from arXiv:1409.1227

New molecules in IRC +10°216: confirmation of C_5S and tentative identification of MgCCH, NCCP, and SiH_3CN

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The carbon-star envelope IRC +10°216 harbors a rich variety of molecules, with more than 80 detected to date. During the course of a λ 3 mm survey of IRC +10°216 carried out with the IRAM 30-m telescope we have detected various weak lines, with antenna temperatures of a few mK, which we assign to rotational transitions of four new molecules. The observation of three lines of C_5S confirms a previous tentative identification of this molecule based on a line at 24.0 GHz. We also report the tentative identification of three molecules not yet observed in space: MgCCH, the first metal acetylide detected in space, and NCCP and SiH_3CN, the phosphorus and silicon analogs of cyanogen (NCCN) and methyl cyanide (CH_3CN). We derive the following column densities: $N(C_5S)$ = (2–14) $\times 10^{12}$ cm^{-2} (depending on the rotational temperature adopted), N(MgCCH) = 2×10^{12} cm^{-2}, N(NCCP) = 7×10^{11} cm^{-2}, and $N(SiH_3CN)$ = 10^{12} cm^{-2}. The S-bearing carbon chain C_5S is less abundant than C_3S, while MgCCH has an abundance in between that of MgNC and those of MgCN and HMgNC. On the other hand, NCCP and SiH_3CN are the least abundant P- and Si-bearing molecules observed to date in IRC +10°216. Based on the behavior of similar molecules it is likely that these four species are formed in the outer circumstellar layers of IRC +10°216. We discuss possible gas-phase formation routes.

Accepted for publication in A&A
Available from arXiv:1408.6306

The complex dust formation zone of the AGB star IRC +10°216 probed with CARMA 0″.25 angular resolution molecular observations

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We present low spectral resolution molecular interferometric observations at 1.2 mm obtained with the Combined Array for Research in Millimetre-wave Astronomy (CARMA) towards the C-rich AGB star IRC +10°216. We have mapped the emission of several lines of SiS, $H^{13}CN$, SiO, and SiC_2 in the ground and first excited vibrational states with a high angular resolution of 0″.25. These observations have allowed us to partially resolve the emission of the envelope at distances from the star < 50 stellar radii ($R_\star$), where the stellar wind is mainly accelerated. The structure of the molecular emission has been modelled with a 3D radiation transfer code. The emission of line SiS ($v = 0$, $J = 14$–13) is best reproduced with a set of maser emitting arcs arranged between 5 and 20 $R_\star$. The abundance of $H^{13}CN$ with respect to H_2 decreases from 8×10^{-7} at 1–5 $R_\star$ to 3×10^{-7} at 20 $R_\star$. The SiO observations are explained with an abundance $< 2 \times 10^{-8}$ in the shell-like region between 1 and 5 $R_\star$. At this point, the SiO abundance sharply increases up to $(2$–$3) \times 10^{-7}$. The vibrational temperature of SiO increases by a factor of 2 due North-East between 20 and 50 $R_\star$. SiC_2 is formed at the stellar surface with an abundance of 8×10^{-7} decreasing down to 8×10^{-8} at 20 $R_\star$ probably due to depletion on to dust grains. Several asymmetries are found in the abundance distributions of $H^{13}CN$, SiO, and SiC_2 which define three remarkable directions (North-East, South-Southwest, and South-East) in the explored region of the envelope. There are some differences between the red- and blue-shifted emissions of these molecules suggesting the existence of additional asymmetries in their abundance distributions along the line-of-sight.

Accepted for publication in MNRAS
Available from arXiv:1409.5833

On the central symmetry of the circumstellar envelope of RS Cnc

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We present a phenomenological study of CO(1–0) and CO(2–1) emission from the circumstellar envelope (CSE) of the Asymptotic Giant Branch (AGB) star RS Cnc. It reveals departures from central symmetry that turn out to be efficient tools for the exploration of some of the CSE properties. We use a wind model including a bipolar flow with a typical wind velocity of ~ 8 km s^{-1} decreasing to ~ 2 km s^{-1} near the equator to describe Doppler velocity spectral maps obtained by merging data collected at the IRAM Plateau de Bure Interferometer and Pico Veleta single dish radio telescope. Parameters describing the wind morphology and kinematics are obtained, together with the radial dependence of the gas temperature in the domain of the circumstellar envelope probed by the CO observations. Significant North-South central asymmetries are revealed by the analysis, which we quantify using a simple phenomenological description. The origin of such asymmetries is unclear.

Accepted for publication in Research in Astronomy and Astrophysics
Available from arXiv:1409.5682

Formation of planetary debris discs around white dwarfs I: Tidal disruption of an extremely eccentric asteroid

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25%–50% of all white dwarfs (WDs) host observable and dynamically active remnant planetary systems based on the presence of close-in circumstellar dust and gas and photospheric metal pollution. Currently-accepted theoretical explanations for the origin of this matter include asteroids that survive the star's giant branch evolution at au-scale distances and are subsequently perturbed onto WD-grazing orbits following stellar mass loss. In this work we investigate the tidal disruption of these highly-eccentric ($e > 0.98$) asteroids as they approach and tidally disrupt around the WD. We analytically compute the disruption timescale and compare the result with fully self-consistent numerical simulations of rubble piles by using the N-body code PKDGRAV. We find that this timescale is highly dependent on the orbit's pericentre and largely independent of its semimajor axis. We establish that spherical asteroids readily break up and form highly eccentric collisionless rings, which do not accrete onto the WD without additional forces such as radiation or sublimation. This finding highlights the critical importance of such forces in the physics of WD planetary systems.

Accepted for publication in MNRAS
Available from arXiv:1409.2493

Post-main-sequence debris from rotation-induced YORP break-up of small bodies

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Although discs of dust and gas have been observed orbiting white dwarfs, the origin of this circumstellar matter is uncertain. We hypothesize that the in-situ breakup of small bodies such as asteroids spun to fission during the giant branch phases of stellar evolution provides an important contribution to this debris. The YORP effect, which arises from radiation pressure, accelerates the spin rate of asymmetric asteroids, which can eventually shear themselves apart. This pressure is maintained and enhanced around dying stars because the outward push of an asteroid due to stellar mass loss is insignificant compared to the resulting stellar luminosity increase. Consequently, giant star radiation will destroy nearly all bodies with radii in the range 100 m − 10 km that survive their parent star's main sequence lifetime within a distance of about 7 au; smaller bodies are spun apart to their strongest, competent components. This estimate is conservative, and would increase for highly asymmetric shapes or incorporation of the inward drag due to giant star stellar wind. The resulting debris field, which could extend to thousands of au, may be perturbed by remnant planetary systems to reproduce the observed dusty and gaseous discs which accompany polluted white dwarfs.

Accepted for publication in MNRAS
Available from arXiv:1409.4412

Fingering convection in red giants revisited

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Fingering (thermohaline) convection has been invoked for several years as a possible extra-mixing which could occur in Red Giant stars due to the modification of the chemical composition induced by nuclear reactions in the hydrogen burning zone. Recent studies show however that this mixing is not sufficient to account for the needed surface abundances. A new prescription for fingering convection, based on 3D numerical simulations has recently been proposed (BGS). The resulting mixing coefficient is larger than the ones previously given in the literature. We compute models using this new coefficient and compare them to previous studies. We use the LPCODE stellar evolution code with the GNA generalized version of the mixing length theory to compute Red Giant models and we introduce fingering convection using the BGS prescription. The results show that, although the fingering zone now reaches the outer dynamical convective zone, the efficiency of the mixing is not enough to account for the observations. The fingering mixing coefficient should be increased by two orders of magnitude for the needed surface abundances to be reached. We confirm that fingering convection cannot be the mixing process needed to account for surface abundances in RGB stars.

Accepted for publication in Astronomy & Astrophysics
Available from arXiv:1409.4216

Internal entrainment and the origin of jet-related broad-band emission in Centaurus A

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The dimensions of Fanaroff–Riley class I jets and the stellar densities at galactic centres imply that there will be numerous interactions between the jet and stellar winds. These may give rise to the observed diffuse and 'knotty' structure of the jets in the X-ray, and can also mass load the jets. We performed modelling of internal entrainment from stars intercepted by Centaurus A's jet, using stellar evolution- and wind codes. From photometry and a code-synthesised population of 12 Gyr ($Z = 0.004$), 3 Gyr ($Z = 0.008$) and 0–60 Myr ($Z = 0.02$) stars, appropriate for the parent elliptical NGC 5128, the total number of stars in the jet is $\sim 8 \times 10^8$. Our model is energetically capable of producing the observed X-ray emission, even without young stars. We also reproduce the radio through X-ray spectrum of the jet, albeit in a downstream region with distinctly fewer young stars, and recover the mean X-ray spectral index. We derive an internal entrainment rate of $\sim 2.3 \times 10^{-3}$ $M_\odot$ yr^{-1} which implies substantial jet deceleration. Our absolute nucleosynthetic yields for the AGB stellar population in the jet show the highest amounts for ^{4}He, ^{16}O, ^{12}C, ^{14}N and ^{20}Ne. If some of the events at ≥ 55 EeV detected by the Pierre Auger Observatory originate from internal entrainment in Centaurus A, we predict that their composition will be largely intermediate-mass nuclei with ^{16}O, ^{12}C and ^{14}N the key isotopes.

Submitted to MNRAS
Available from arXiv:1409.5785

ALMA reveals VY CMa's sub-mm maser and dust distribution

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Cool, evolved stars have copious, enriched winds. The structure of these winds and the way they are accelerated is not well known. We need to improve our understanding by studying the dynamics from the pulsating stellar surface to about 10 stellar radii, where radiation pressure on dust is fully effective. Some red supergiants have highly asymmetric nebulae, implicating additional forces. We retrieved ALMA Science Verification data providing images of sub-mm line and continuum emission from VY CMa. This enables us to locate water masers with milli-arcsec precision and resolve the dusty continuum. The 658-, 321- and 325-GHz masers lie in irregular, thick shells at increasing distances from the centre of expansion. For the first time this is confirmed as the stellar position, coinciding with a compact peak offset to the NW of the brightest continuum emission. The maser shells (and dust formation zone) overlap but avoid each other on tens-au scales. Their distribution is broadly consistent with excitation models but the conditions and kinematics appear to be complicated by wind collisions, clumping and asymmetries.

Submitted to A&A

Available from arXiv:1409.5497

Hydrogen delivery onto white dwarfs from remnant exo-Oort cloud comets

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The origin of trace hydrogen in white dwarfs (WDs) with He-dominated atmospheres is a long-standing problem, one that cannot satisfactorily be explained by the historically favoured hypothesis of accretion from the interstellar medium. Here we explore the possibility that the gradual accretion of exo-Oort cloud comets, which are a rich source of H, contributes to the apparent increase of trace H with WD cooling age. We determine how often remnant exo-Oort clouds, freshly excited from post-main-sequence stellar mass loss, dynamically inject comets inside the WD's Roche radius. We improve upon previous studies by considering a representative range of single WD masses (0.52–1.00 $M_\odot$) and incorporating different cloud architectures, giant branch stellar mass loss, stellar flybys, Galactic tides and a

realistic escape ellipsoid in self-consistent numerical simulations that integrate beyond 8 Gyr ages of WD cooling. We find that $\sim 10^{-5}$ of the material in an exo-Oort cloud is typically amassed onto the WD, and that the H deposits accumulate even as the cloud dissipates. This accumulation may account for the relatively large amount of trace H, 10^{22}–10^{25} g, that is determined frequently among WDs with cooling ages ≥ 1 Gyr. Our results also reaffirm the notion that exo-Oort cloud comets are not the primary agents of the metal budgets observed in polluted WD atmospheres.

Accepted for publication in Monthly Notices of the Royal Astronomical Society
Available from arXiv:1409.7691

Conference Paper

Toward a self consistent MHD model of chromospheres and winds from late type evolved stars

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We present the first magnetohydrodynamic model of the stellar chromospheric heating and acceleration of the outer atmospheres of cool evolved stars, using α Tau as a case study. We used a 1.5D MHD code with a generalized Ohm's law that accounts for the effects of partial ionization in the stellar atmosphere to study Alfvén wave dissipation and wave reflection. We have demonstrated that due to inclusion of the effects of ion-neutral collisions in magnetized weakly ionized chromospheric plasma on resistivity and the appropriate grid resolution, the numerical resistivity becomes 1–2 orders of magnitude smaller than the physical resistivity. The motions introduced by non-linear transverse Alfvén waves can explain non-thermally broadened and non-Gaussian profiles of optically thin UV lines forming in the stellar chromosphere of α Tau and other late-type giant and supergiant stars. The calculated heating rates in the stellar chromosphere due to resistive (Joule) dissipation of electric currents, induced by upward propagating non-linear Alfvén waves, are consistent with observational constraints on the net radiative losses in UV lines and the continuum from α Tau. At the top of the chromosphere, Alfvén waves experience significant reflection, producing downward propagating transverse waves that interact with upward propagating waves and produce velocity shear in the chromosphere. Our simulations also suggest that momentum deposition by non-linear Alfvén waves becomes significant in the outer chromosphere at 1 stellar radius from the photosphere. The calculated terminal velocity and the mass loss rate are consistent with the observationally derived wind properties in α Tau.

Poster contribution, published in "8^{th} Cambridge Workshop on Cool Stars, Stellar Systems, and the Sun", 9–13 June 2014, eds. G. van Belle & H. Harris, Proceedings of Lowell Observatory
Available from arXiv:1409.3833

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