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. 140 — 1 March 2009

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 140$^{\text{th}}$ issue of the AGB Newsletter. It is impossible to do justice summarising such a delicious cocktail of new results, and so we warmly invite you to dive in and taste it for yourself. Do not forget to also check several extremely interesting conference papers and beautiful reviews on varied topics within our field.

There appears to be some worry within our community, that brilliant students and junior researchers are not attracted to the field of astrophysics, and that they are not always presented with adequate training opportunities. This depletes our research from both past wisdom and expertise and fresh minds. It is probably one of the reasons we still do not understand why low-mass stars become red giants! It is in our own interest — and that of scientific progress — to ameliorate this situation.

The next issue will be distributed on the 1$^{\text{st}}$ of April 2009; the deadline for contributions is the 31$^{\text{st}}$ of March.

Editorially Yours,
Jacco van Loon and Albert Zijlstra

Food for Thought

This month's thought-provoking statement is:

Why do low-mass stars become red giants? (to be continued)

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)

High-resolution spectroscopic observations of two chemically peculiar metal-poor stars: HD 10613 & BD+04°2466

C.B. Pereira[1] *and N. Drake*[2]

[1]Observatorio Nacional/MCT, Brazil

[2]Sobolev Astronomical Institute, St. Petersburg State University, Russia

Aims : We determined the atmospheric parameters and abundance pattern of two chemically peculiar metal-poor stars: HD 10613 and BD+04°2466 in order to better understand their evolutionary state and the nature of the s-element enhancement of these stars.
Methods : We used high resolution optical spectroscopy. Atmospheric parameters and abundances were determined in the local-thermodynamic-equilibrium model atmospheres of Kurucz using the spectral analysis code MOOG.
Results : We conclude that HD 10613 is another metal-poor barium star with C/O = 0.52 and [Fe/H] = −0.82, while BD+04°2466 is a CH star with C/O = 3.6 and [Fe/H] = −1.92 rather than a metal-deficient barium star as was previously classified. BD+04°2466 appear to be enriched in lead with [Pb/Ce] = +0.85 and [Pb/La] = +0.72. For BD+04°2466 the abundance of lead is in agreement with predictions from AGB models.Due to the low luminosity of these two stars, their observed s-process overabundance is better explained by mass-transfer in the past from an AGB star.

Accepted for publication in Astronomy & Astrophysics

Ubiquitous Hα polarized line profiles: Absorptive spectropolarimetric effects and temporal variability in Post-AGB, Herbig Ae/Be and other stellar types.

D.M. Harrington[1] *and J.R. Kuhn*[1]

[1]Institute for Astronomy, University of Hawaii, 2680 Woodlawn Drive, Honolulu, HI 96822, USA

We show here that the absorptive Hα polarized line profile previously seen in many Herbig Ae/Be (HAeBe) stars is a nearly ubiquitous feature of other types of embedded or obscured stars. This characteristic 1% linear polarization variation across the absorptive part of the Hα line is seen in Post-AGB stars as well as RV Tau, δ Scuti, and other types. Each of these stars shows evidence of obscuration by intervening circumstellar hydrogen gas and the polarization effect is in the absorptive component, consistent with an optical pumping model. We present ESPaDOnS spectropolarimetric observations of 9 post-AGB and RV Tau types in addition to many multi-epoch HiVIS observations of these targets. We find significant polarization changes across the Hα line in 8/9 stars with polarization amplitudes of 0.5% to over 3% (5/6 Post-AGB and 3/3 RV Tau). In all but one of these, the polarization change is dominated by the absorptive component of the line profile. There is no evidence that subclasses of obscured stars showing stellar pulsations (RV Tau for Post-AGB stars and δ Scuti for Herbig Ae/Be stars) show significant spectropolarimetric differences from the main class. Significant temporal variability is evident from both HiVIS and ESPaDOnS data for several stars presented here: 89 Her, AC Her, SS Lep, MWC 120, AB Aurigae and HD 144668. The morphologies and temporal variability are comparable to existing large samples of Herbig Ae/Be and Be type stars. Since Post-AGB stars have circumstellar gas that is very different from Be stars, we discuss these observations in the context of their differing environments.

Accepted for publication in Astrophysical Journal
Available from arXiv:0812.2598

The mixed chemistry phenomenon in Galactic Bulge Planetary Nebulae

J. V. Perea-Calderón[1], *D. A. García-Hernández*[2], *P. García-Lario*[3], *R. Szczerba*[4] *and M. Bobrowsky*[5]

[1]European Space Astronomy Centre, INSA S.A. P.O. Box 78, E-28080 Madrid, Spain

[2]Instituto de Astrofisica de Canarias, C/ Via Lactea s/n, 38200 La Laguna, Spain

[3]Herschel Science Centre. European Space Astronomy Centre, Research and Scientific Support Department of ESA, Villafranca del Castillo, P.O. Box 78, E-28080 Madrid, Spain

[4]N. Copernicus Astronomical Center, Rabianska 8, 87-100 Torun, Poland

[5]Department of Physics. University of Maryland, College Park, MD 20742-4111, USA

We investigate the dual-dust chemistry phenomenon in planetary nebulae (PNe) and discuss reasons for its occurrence, by analyzing Spitzer/IRS spectra of a sample of 40 Galactic PNe among which 26 belong to the Galactic Bulge (GB). The mixed chemistry is derived from the simultaneous detection of Polycyclic Aromatic Hydrocarbon (PAH) features in the 6–14 μm range and crystalline silicates beyond 20 μm in the Spitzer/IRS spectra. Out of the 26 planetary nebulae observed in the Galactic Bulge, 21 show signatures of dual-dust chemistry. Our observations reveal that the simultaneous presence of oxygen and carbon-rich dust features in the infrared spectra of [WC]-type planetary nebulae is not restricted to late/cool [WC]-type stars, as previously suggested in the literature, but is a common feature associated with all [WC]-type planetary nebulae. Surprisingly, we found that the dual-dust chemistry is seen also in all observed weak emission-line stars (wels), as well as in other planetary nebulae with central stars being neither [WC] nor wels. Most sources observed display crystalline silicate features in their spectra, with only a few PNe exhibiting, in addition, amorphous silicate bands. We appear to detect a recent change of chemistry at the end of the Asymptotic Giant Branch (AGB) evolution in the low-mass, high-metallicity population of GB PNe observed. The deficit of C-rich AGB stars in this environment suggests that the process of PAH formation in PNe occurs at the very end of the AGB phase. In addition, the population of low-mass, O-rich AGB stars in the Galactic Bulge, do not exhibit crystalline silicate features in their spectra. Thus, the high detection rate of dual-dust chemistry that we find cannot be explained by long-lived O-rich (primordial or circumbinary) disks. Our most plausible scenario is a final thermal pulse on the AGB (or just after), which could produce enhanced mass loss, capable of removing/mixing (sometimes completely) the remaining H-rich envelope and exposing the internal C-rich layers, and generating shocks responsible for the silicate crystallization.

Accepted for publication in A&A Letters
Available from arXiv:0902.1049
and from http://www.iac.es/folleto/research/preprints/?c=view&pre_id=9011

Effects of α-Element Enhancement and the Thermally Pulsing-Asymptotic Giant Branch on Surface Brightness Fluctuation Magnitudes and Broadband Colors

Hyun-chul Lee[1], *Guy Worthey*[1] *and John P. Blakeslee*[2]

[1]Washington State University, USA

[2]Herzberg Institute of Astrophysics, Canada

We investigate the effects of α-element enhancement and the thermally pulsing-asymptotic giant branch (TP-AGB) stars on the surface brightness fluctuation (SBF) magnitudes and broadband colors of simple stellar populations and compare to the empirical calibrations. We consider a broad range of ages and metallicities using the recently updated Teramo BaSTI isochrones. We find that the alpha-element enhanced I-band SBF magnitudes are brighter and their integrated V–I colors are redder, mostly because of oxygen enhancement effects on the upper red giant branch and asymptotic giant branch. The Teramo BaSTI and Padova isochrones that include TP-AGB stars fit the I-band and near-IR SBF empirical trends better than past models. Our results indicate that α-enhanced SBF models may be necessary to match red massive galaxies, while solar-scaled models may be adequate to match bluer galaxies.

Submitted to The Astrophysical Journal
Available from arXiv:0902.1177

On the Age and Metallicity Estimation of Spiral Galaxies Using Optical and Near-Infrared Photometry

Hyun-chul Lee[1], *Guy Worthey*[1], *Scott C. Trager*[2] *and Sandra M. Faber*[3]

[1]Washington State University, USA

[2]Kapteyn Astronomical Institute, The Netherlands

[3]University of California, Santa Cruz, USA

In integrated-light, some color–color diagrams that use optical and near-infrared photometry show surprisingly orthogonal grids as age and metallicity are varied, and they are coming into common usage for estimating the average age and metallicity of spiral galaxies. In this paper we reconstruct these composite grids using simple stellar population models from several different groups convolved with some plausible functional forms of star formation histories at fixed metallicity. We find that the youngest populations present ($t < 2$ Gyr) dominate the light, and because of their presence the age–metallicity degeneracy can be partially broken with broad-band colors, unlike older populations. The scatter among simple stellar population models by different authors is, however, large at ages $t < 2$ Gyr. The dominant uncertainties in stellar population models arise from convective core overshoot assumptions and the treatment of the thermally pulsing asymptotic giant branch phase and helium abundance may play a significant role at higher metallicities. Real spiral galaxies are unlikely to have smooth, exponential star formation histories, and burstiness will cause a partial reversion to the single-burst case, which has even larger model-to-model scatter. Finally, it is emphasized that the current composite stellar population models need some implementation of chemical enrichment histories for the proper analysis of the observational data.

Published in The Astrophysical Journal
Available from arXiv:0605425

The Chemical Evolution of Globular Clusters I. Reactive Elements and Non-Metals

Andrea Marcolini[1], *Brad K. Gibson*[1], *Amanda I. Karakas*[2] *and Patricia Sánchez-Blázquez*[1,3]

[1]Jeremiah Horrocks Institute for Astrophysics and Supercomputing, University of Central Lancashire, Preston, PR1 2HE, UK

[2]Research School of Astronomy & Astrophysics, Mt. Stromlo Observatory, Weston Creek, ACT 2611, Australia

[3]Instituto de Astrofísica de Canarias, c/Via Lactea S/N, E38205, La Laguna, Spain

We propose a new chemical evolution model aimed at explaining the chemical properties of globular clusters (GC) stars. Our model depends upon the existence of (i) a peculiar pre-enrichment phase in the GC's parent galaxy associated with very low-metallicity Type II supernovae (SNeII), and (ii) localized inhomogeneous enrichment from a single Type Ia supernova (SNeIa) and intermediate-mass (4–7 $M_\odot$) asymptotic giant branch(AGB) feld stars. GC formation is then assumed to take place within this chemically-peculiar region. Thus, in our model the first low-mass GC stars to form are those with peculiar abundances (i.e., O-depleted and Na-enhanced) while "normal" stars (i.e., O-rich and Na-depleted) are formed in a second stage when self-pollution from SNeII occurs and the peculiar pollution from the previous phase is dispersed. In this study, we focus on three different GCs: NGC 6752, NGC 6205 (M 13) and NGC 2808. We demonstrate that, within this framework, a model can be constructed which is consistent with (i) the elemental abundance anti-correlations, (ii) isotopic abundance patterns, and (iii) the extreme [O/Fe] values observed in NGC 2808 and M 13, without violating the global constraints of approximately unimodal [Fe/H] and C+N+O.

Accepted for publication in MNRAS
Available from arXiv:0902.0571

The Dynamical Effects of White Dwarf Birth Kicks in Globular Star Clusters

John M. Fregeau[1,2], *Harvey B. Richer*[3], *Frederic A. Rasio*[4] *and Jarrod R. Hurley*[5]

[1]Kavli Institute for Theoretical Physics, UCSB, USA

[2]Chandra Fellow

[3]University of British Columbia, Canada

[4]Northwestern University, USA

[5]Swinburne University of Technology, Australia

Recent observations of the white dwarf (WD) populations in globular clusters suggest that WDs receive a kick of a few km s^{-1} shortly before they are born. Using our Monte Carlo cluster evolution code, which includes accurate treatments of all relevant physical processes operating in globular clusters, we study the effects of the kicks on the cluster and on the WD population itself. We find that in clusters whose velocity dispersion is comparable to the kick speed, WD kicks are a significant energy source for the cluster, prolonging the initial cluster core contraction phase significantly so that at late times the cluster core to half-mass radius ratio is a factor of up to ~ 10 larger than in the no-kick case. WD kicks thus represent a possible resolution of the large discrepancy between observed and theoretically predicted values of this key structural parameter. Our modeling also reproduces the observed trend for younger WDs to be more extended in their radial distribution in the cluster than older WDs.

Submitted to ApJ Letters
Available from arXiv:0902.1166

Discovery of the first symbiotic star in NGC 6822

Alexei Kniazev[1,2], *Petri Vaisanen*[1,2], *Patricia A. Whitelock*[1,3] *and et al.*

[1]SAAO, South Africa

[2]SALT Foundation, South Africa

[3]University of Cape Town, South Africa

We report the discovery of the first symbiotic star ($V = 21.6$, $K_{\rm s} = 15.8$ mag) in the Local Group dwarf irregular galaxy NGC 6822. This star was identified during a spectral survey of Hα emission-line objects using the Southern African Large Telescope (SALT) during its performance-verification phase. The observed strong emission lines of H I and He II suggest a high electron density and $T_\star < 130,000$ K for the hot companion. The infrared colours allow us to classify this object as an S-type symbiotic star, comprising a red giant losing mass to a compact companion. The red giant is an AGB carbon star, and a semi-regular variable, pulsating in the first overtone with a period of 142 days. Its bolometric magnitude is $M_{\rm bol} = -4.4$ mag. We review what is known about the luminosities of extragalactic symbiotic stars, showing that most, possibly all, contain AGB stars. We suggest that a much larger fraction of Galactic symbiotic stars may contain AGB stars than was previously realised.

Accepted for publication in MNRAS
Available from arXiv:0902.1648

Evolution, nucleosynthesis and yields

S. Cristallo[1], *O. Straniero*[1], *R. Gallino*[2], *L. Piersanti*[1], *I. Domínguez*[3] *and M.T. Lederer*[4]

[1]Osservatorio Astronomico Teramo (INAF) - Italy

[2]Università di Torino - Italy

[3]Universidad de Granada - Spain

[4]University of Wien - Austria

The envelope of thermally pulsing AGB stars undergoing periodic third dredge-up episodes is enriched in both light and heavy elements, the ashes of a complex internal nucleosynthesis involving p, α and n captures over hundreds of stable and unstable isotopes. In this paper, new models of low-mass AGB stars (2 $M_{\odot}$), with metallicity ranging between Z=0.0138 (the solar one) and Z=0.0001, are presented. Main features are: i) a full nuclear network (from H to Bi) coupled to the stellar evolution code, ii) a mass-loss–period–luminosity relation, based on available data for long period variables, and ii) molecular and atomic opacities for C- and/or N-enhanced mixtures, appropriate for the chemical modifications of the envelope caused by the third dredge up. For each model a detailed description of the physical and chemical evolution is presented; moreover, we present a uniform set of yields, comprehensive of all chemical species (from hydrogen to bismuth). The main nucleosynthesis site is the thin ^{13}C pocket, which forms in the core-envelope transition region after each third dredge up episode. The formation of this ^{13}C pockets is the principal by-product of the introduction of a new algorithm, which shapes the velocity profile of convective elements at the inner border of the convective envelope: both the physical grounds and the calibration of the algorithm are discussed in detail. We find that the pockets shrink (in mass) as the star climbs the AGB, so that the first pockets, the largest ones, leave the major imprint on the overall nucleosynthesis. Neutrons are released by the ^{13}C(α,n)^{16}O reaction during the interpulse phase in radiative conditions, when temperatures within the pockets attain $T \sim 1.0 \times 10^8$ K, with typical densities of ($10^6 \div 10^7$) neutrons $\times$ cm^{-3}. Exceptions are found, as in the case of the first pocket of the metal-rich models (Z = 0.0138, Z = 0.006 and Z = 0.003), where the ^{13}C is only partially burned during the interpulse: the surviving part is ingested in the convective zone generated by the subsequent thermal pulse and then burned at $T \sim 1.5 \times 10^8$ K, thus producing larger neutron densities (up to 10^{11} neutrons $\times$ cm^{-3}). An additional neutron exposure, caused by the ^{22}Ne(α,n)^{25}Mg during the thermal pulses, is marginally activated at large Z, but becomes an important nucleosynthesis source at low Z, when most of the ^{22}Ne is primary. The final surface compositions of the various models reflect the differences in the initial iron-seed content and in the physical structure of AGB stars belonging to different stellar populations. Thus, at large metallicities the nucleosynthesis of light s elements (Sr,Y,Zr) is favored, whilst, decreasing the iron content, the overproduction of heavy s elements (Ba,La,Ce,Nd,Sm) and lead becomes progressively more important. At low metallicities (Z=0.0001) the main product is lead. The agreement with the observed [hs/ls] index observed in intrinsic C stars at different [Fe/H] is generally good. For the solar metallicity model, we found an interesting overproduction of some radioactive isotopes, like ^{60}Fe, as a consequence of the anomalous first ^{13}C pocket. Finally, light elements (C, F, Ne and Na) are enhanced at any metallicity.

Accepted for publication in ApJ
Available from arXiv:0902.0243

The circumstellar envelopes of the Cepheids L Car and RS Pup — Comparative study in the infrared with Spitzer, VLT/VISIR and VLTI/MIDI

Pierre Kervella[1], *Antoine Mérand*[2] *and Alexandre Gallenne*[2,1]

[1]Observatoire de Paris, LESIA, Meudon, France

[2]European Southern Observatory, Vitacura, Chile

Context: Compact circumstellar envelopes (CSEs) have been detected around several Cepheids by interferometry. In particular, observations with the VINCI instrument revealed in 2006 a compact envelope around the long period Cepheid L Car (P = 35.5 days). Another Cepheid, RS Pup (P = 41.4 days), presents a large ($\sim 2'$) circumstellar nebula scattering the Cepheid light in the visible. These envelopes are particularly interesting for two reasons: their presence could impact the Cepheid distance scale, and they could imply stellar mass loss.
Aims: Our goal is to establish the spatial and spectral properties of the CSEs of L Car and RS Pup. This is done through a parametrization of the envelopes in terms of fractional flux (with respect to the star) and angular size.
Methods: We retrieved archival Spitzer images of the two stars (3.5–70 μm), and obtained new diffraction-limited imaging with the VLT/VISIR camera in BURST mode (8.6–11.9 μm), as well as interferometric observations with the VLTI/MIDI beam combiner (8–13 μm). This combination of single-telescope and interferometric techniques allows us to probe the envelopes of the two Cepheids over a broad range of angular scales, from arcminutes to milliarcseconds.
Results: The circumstellar envelope of RS Pup is resolved spatially at 24 and 70 μm by Spitzer, and around 10 μm by MIDI and VISIR. The envelope of L Car appears much more compact, and is resolved only in the VISIR and

MIDI observations. The infrared excesses we detect around RS Pup and L Car are both very significant, but differ considerably in spectral and spatial properties. We detect a warm component in the CSE of both stars at a spatial scale of a few 100 to a few 1,000 AU. In addition, RS Pup presents a very large (several 100,000 AU) and cold (~ 40 K) dusty envelope.
Conclusions: The observed properties of the CSEs lead us to propose that the cold dust content of the large reflection nebula surrounding RS Pup has an interstellar origin, while the warm CSEs of the two stars were created by ongoing stellar mass loss. We also speculate that the NGC 7023 reflection nebula surrounding the Herbig Be star HD 200775 is an analogue of RS Pup at an age of 100,000 years. The presence of CSEs around the two brightest long-period Cepheids is an indication that many long-period members of this class, if not all, could be surrounded by warm circumstellar envelopes created by mass loss. However, very large dusty envelopes such as that of RS Pup are probably less common, as according to our scenario, they require the presence of a high dust density in the interstellar medium (ISM) at the time of the formation of the Cepheid progenitor.

Accepted for publication in Astronomy & Astrophysics
Available from arXiv:0902.1588
and from http://hal.archives-ouvertes.fr/hal-00358742/en/

A large C+N+O abundance spread in giant stars of the globular cluster NGC 1851

David Yong[1], Frank Grundahl[2], Francesca D'Antona[3], Amanda I. Karakas[1], John C. Lattanzio[4] and John E. Norris[1]

[1]RSAA, Mt. Stromlo Observatory, Australia
[2]Univ. of Aarhus, Denmark
[3]INAF Osservatorio di Roma, Italy
[4]CSPA, Monash University, Australia

Abundances of C, N, and O are determined in four bright red giants that span the known abundance range for light (Na and Al) and *s*-process (Zr and La) elements in the globular cluster NGC 1851. The abundance sum C+N+O exhibits a range of 0.6 dex, a factor of 4, in contrast to other clusters in which no significant C+N+O spread is found. Such an abundance range offers support for the Cassisi et al. (2008) scenario in which the double subgiant branch populations are coeval but with different mixtures of C+N+O abundances. Further, the Na, Al, Zr, and La abundances are correlated with C+N+O, and therefore, NGC 1851 is the first cluster to provide strong support for the scenario in which AGB stars are responsible for the globular cluster light element abundance variations.

Accepted for publication in ApJ Letters
Available from arXiv:0902.1773

Why do low-mass stars become red giants?

Richard J. Stancliffe[1], Alessandro Chieffi[2], John C. Lattanzio[1] and Ross P. Church[1]

[1]Centre for Stellar and Planetary Astrophysics, Monash University, Australia
[2]INAF - Instituto di Astrofisica, Spaziale e Fisica Cosmica, Italy

We revisit the problem of why stars become red giants. We modify the physics of a standard stellar evolution code in order to determine what does and what does not contribute to a star becoming a red giant. In particular, we have run tests to try to separate the effects of changes in the mean molecular weight and in the energy generation. The implications for why stars become red giants are discussed. We find that while a change in the mean molecular weight is necessary (but not sufficient) for a 1 $M_{\odot}$ star to become a red giant, this is not the case in a star of 5 $M_{\odot}$. It therefore seems that there may be more than one way to make a giant.

Accepted for publication in PASA
Available from arXiv:0902.0406

Evolution of the Barium abundance in the early Galaxy from a NLTE analysis of the Ba lines in a homogeneous sample of EMP stars

S.M. Andrievsky[1,2], *M. Spite*[1], *S.A. Korotin*[2], *F. Spite*[1], *P. François*[1], *P. Bonifacio*[1,3,4] *and R. Cayrel*[1]

[1]GEPI, Observatoire de Paris,CNRS, Univ. Paris Diderot, F-92195 Meudon Cedex, France

[2]Department of Astronomy and Astronomical Observatory, Odessa National University, Isaac Newton Institute of Chile, Odessa branch, Shevchenko Park, 65014 Odessa, Ukraine

[3]CIFIST Marie Curie Excellence Team

[4]Istituto Nazionale di Astrofisica, Osservatorio Astronomico di Trieste, Via Tiepolo 11, I-34143 Trieste, Italy

Context: Barium is a key element in constraining the evolution of the (not well understood) r-process in the first galactic stars and currently the Ba abundances in these very metal-poor stars were mostly measured under the Local Thermodynamical Equilibrium (LTE) assumption, which may lead in general to an underestimation of Ba.
Aims: We present here determinations of the barium abundance taking into account the non-LTE (NLTE) effects in a sample of extremely metal-poor stars (EMP stars): 6 turnoff stars and 35 giants.
Methods: The NLTE profiles of the three unblended Ba I lines (4554, 5853, 6496 Å) have been computed. The computations were made with a modified version of the MULTI code, applied to an atomic model of the Ba atom with 31 levels of Ba I, 101 levels of Ba II, and compared to the observations.
Results: The ratios of the NLTE abundances of barium relative to Fe are slightly shifted towards the solar ratio. In the plot of [Ba/Fe] versus [Fe/H], the slope of the regression line is slightly reduced as is the scatter. In the interval $-3.3 <$[Fe/H]< -2.6, [Ba/Fe] decreases with [Fe/H] with a slope of about 1.4 and a scatter close to 0.44. For [Fe/H]< -3.3, the number of stars is not sufficient to decide whether [Ba/Fe] keeps decreasing (and then CD−38:245 should be considered as a peculiar "barium-rich star") or if a plateau is reached as soon as [Ba/Fe]~ -1. In both cases the scatter remains quite large, larger than what can be accounted for by the measurement and determination errors, suggesting the influence of a complex process of Ba production, and/or inefficient mixing in the early Galaxy.

Accepted for publication in A&A
Available from arXiv:0902.0450

Optical constants of silicon carbide for astrophysical applications. II. Extending optical functions from IR to UV using single-crystal absorption spectra

A. M. Hofmeister[1], *K. M. Pitman*[1], *A. F. Goncharov*[2] *and A. K. Speck*[3]

[1]Washington University St. Louis, USA

[2]Geophysical Laboratory, Carnegie Institution of Washington, USA

[3]University of Missouri, USA

Laboratory measurements of unpolarized and polarized absorption spectra of various samples and crystal stuctures of silicon carbide (SiC) are presented from 1200–35,000 cm^{-1} ($\lambda \sim$8–0.28 μm) and used to improve the accuracy of optical functions (n and k) from the infrared (IR) to the ultraviolet (UV). Comparison with previous $\lambda \sim$ 6–20 μm thin-film spectra constrains the thickness of the films and verifies that recent IR reflectivity data provide correct values for k in the IR region. We extract n and k needed for radiative transfer models using a new "difference method", which utilizes transmission spectra measured from two SiC single-crystals with different thicknesses. This method is ideal for near-IR to visible regions where absorbance and reflectance are low and can be applied to any material. Comparing our results with previous UV measurements of SiC, we distinguish between chemical and structural effects at high frequency. We find that for all spectral regions, 3C (β-SiC) and the $\vec{E}\perp\vec{c}$ polarization of 6H (a type of α-SiC) have almost identical optical functions that can be substituted for each other in modeling astronomical environments. Optical functions for $\vec{E}\|\vec{c}$ of 6H SiC have peaks shifted to lower frequency, permitting identification of this structure below $\lambda \sim 4$ μm. The onset of strong UV absorption for pure SiC occurs near 0.2 μm, but the presence of impurities redshifts the rise to 0.33 μm. Optical functions are similarly impacted. Such large differences in spectral characteristics due to structural and chemical effects should be observable and provide a means to distinguish chemical variation of SiC dust in space.

Accepted for publication in Astrophysical Journal
Available from arXiv:0902.2992

Collimated Fast Wind in the Pre-Planetary Nebula CRL 618

C.-F. Lee[1], M.-C. Hsu[1] and R. Sahai[2]

[1]Academia Sinica, Taipei, Taiwan
[2]JPL/NASA, USA

Collimated fast winds (CFWs) have been proposed to operate during the post-AGB evolutionary phase (and even earlier during the late AGB phase), responsible for the shaping of pre-planetary nebulae (PPNs) and young planetary nebulae (PNs). This paper is a follow-up to our previous study of CFW models for the well-studied PPN CRL 618. Previously, we compared our CFW models with optical observations of CRL 618 in atomic and ionic lines and found that a CFW with a small opening angle can readily reproduce the highly collimated shape of the northwestern (W1) lobe of CRL 618 and the bow-like structure seen at its tip. In this paper, we compare our CFW models with recent observations of CRL 618 in CO $J = 2$–1, $J = 6$–5, and H_2 1–0 S(1). In our models, limb-brightened shell structures are seen in CO and H_2 at low velocity arising from the shocked AGB wind in the shell, and can be identified as the low-velocity (LV) components in the observations. However, the shell structure in CO $J = 2$–1 is significantly less extended than that seen in the observations. None of our models can properly reproduce the observed high-velocity (HV) molecular emission near the source along the body of the lobe. In order to reproduce the HV molecular emission in CRL 618, the CFW is required to have a different structure. One possible CFW structure is the cylindrical jet, with the fast wind material confined to a small cross section and collimated to the same direction along the outflow axis.

Accepted for publication in ApJ
Available from http://www.asiaa.sinica.edu.tw/∼cflee/research_publication.html

CO in OH/IR stars close to the Galactic centre

A. Winnberg[1], S. Deguchi[2], M. J. Reid[3], J. Nakashima[4,5], H. Olofsson[1,6] and H. J. Habing[7]

[1]Onsala Space Observatory, Sweden
[2]Nobeyama Radio Observatory, Japan
[3]Harvard-Smithsonian Center for Astrophysics, USA
[4]Academia Sinica Institute of Astronomy and Astrophysics, Taiwan
[5]Department of Physics, University of Hong Kong, China
[6]Stockholm Observatory, Sweden
[7]Sterrewacht Leiden, The Netherlands

Aims: A pilot project has been carried out to measure circumstellar CO emission from three OH/IR stars close to the Galactic centre. The intention was to find out whether it would be possible to conduct a large-scale survey for mass-loss rates using, for example, the Atacama Large Millimeter Array (ALMA). Such a survey would increase our understanding of the evolution of the Galactic bulge.
Methods: Two millimetre-wave instruments were used: the Nobeyama Millimeter Array at 115 GHz and the Submillimeter Array at 230 GHz. An interferometer is necessary as a 'spatial filter' in this region of space because of the confusion with *inter*stellar CO emission.
Results: Towards two of the stars, CO emission was detected with positions and radial velocities coinciding within the statistical errors with the corresponding data of the associated OH sources. However, for one of the stars the line profile is not what one expects for an unresolved expanding circumstellar envelope. We believe that this CO envelope is partially resolved and that this star therefore is a foreground star not belonging to the bulge.
Conclusions: The results of the observations have shown that it is possible to detect line profiles of circumstellar CO from late-type stars both within and in the direction of the Galactic bulge. ALMA will be able to detect CO emission in short integrations with sensitivity sufficient to estimate mass-loss rates from a large number of such stars.

Accepted for publication in Astronomy and Astrophysics
Available from arXiv:0902.2347
and from http://www.aoc.nrao.edu/∼gcnews/

Mass Outflow and Chromospheric Activity of Red Giant Stars in Globular Clusters II. M 13 and M 92

Sz. Mészáros[1,2,3], *A. K. Dupree*[1,4] *and T. Szalai*[2,5]

[1]Harvard-Smithsonian Center for Astrophysics, Cambridge, MA 02138, USA

[2]Department of Optics and Quantum Electronics, University of Szeged, 6701 Szeged, Hungary

[3]meszi@cfa.harvard.edu

[4]adupree@cfa.harvard.edu

[5]szaszi@titan.physx.u-szeged.hu

High resolution spectra of 123 red giant stars in the globular cluster M 13 and 64 red giant stars in M 92 were obtained with Hectochelle at the MMT telescope. Emission and line asymmetries in Hα, and Ca K are identified, characterizing motions in the extended atmospheres and seeking differences attributable to metallicity in these clusters and M 15. On the red giant branch, emission in Hα generally appears in stars with $T_{\rm eff} < 4500$ K and $\log L/{\rm L}_{\odot} > 2.75$. Fainter stars showing emission are asymptotic giant branch (AGB) stars or perhaps binary stars. The line-bisector for Hα reveals the onset of chromospheric expansion in stars more luminous than $\log L/{\rm L}_{\odot} \sim 2.5$ in all clusters, and this outflow velocity increases with stellar luminosity. However, the coolest giants in the metal-rich M 13 show greatly reduced outflow in Hα most probably due to decreased $T_{\rm eff}$ and changing atmospheric structure. The Ca K_3 outflow velocities are larger than shown by Hα at the same luminosity and signal accelerating outflows in the chromospheres. Stars clearly on the AGB show faster chromospheric outflows in Hα than RGB objects. While the Hα velocities on the RGB are similar for all metallicities, the AGB stars in the metal-poor M 15 and M 92 have higher outflow velocities than in the metal-rich M 13. Comparison of these chromospheric line profiles in the paired metal-poor clusters, M 15 and M 92 shows remarkable similarities in the presence of emission and dynamical signatures, and does not reveal a source of the 'second-parameter' effect.

Accepted for publication in Astronomical Journal
Available from arXiv:0902.3367

Photometric analysis of Magellanic Cloud R Coronae Borealis Stars

Robyn M. Woollands[1], *P.L. Cottrell*[1] *and A. Udalski*[2]

[1]Dept. of Physics & Astronomy, University of Canterbury, Christchurch, New Zealand

[2]Warsaw University Observatory, Poland

This paper presents the initial results of a multi-site photometric programme to examine the extraordinary behaviour displayed by 18 R Coronae Borealis (RCB) stars in the Magellanic Clouds (MCs). RCB stars exhibit a unique variability whereby they undergo rapid declines of up to several magnitudes. These are thought to be caused by the formation of dust in the stellar environment which reduces the brightness. The monitoring programme comprised the collection of UBV RI photometric data using five telescopes located at three different southern hemisphere longitudes (Las Campanas Observatory in Chile, Mount Joun University Observatory in New Zealand, and the Southern African Large Telescope (SALT) in South Africa). Examination of the data acquired in the V and I filters resulted in the identification of a total of 18 RCB declines occurring in four stars. Construction of colour–magnitude diagrams (V vs. V–I), during the recovery to maximum light were undertaken in order to study the unique colour behaviour associated with the RCB declines. The combined recovery slope for the four stars was determined to be 3.37 ± 0.24, which is similar to the value of 3.1 ± 0.1 calculated for galactic RCB stars (Skuljan et al. 2003). These results may imply that the nature of the dust (i.e. the particle size) is similar in both our Galaxy and the MCs.

Accepted for publication in Publications of the Astronomical Society of Australia
Available from arXiv:0902.1212

The dust condensation sequence in red supergiant stars

T. Verhoelst[1,2], *N. Van der Zypen*[1], *S. Hony*[3], *L. Decin*[1], *J. Cami*[4] *and K. Eriksson*[5]

[1]Instituut voor Sterrenkunde, K.U. Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium

[2]University of Manchester, Jodrell Bank Centre for Astrophysics, Manchester, M13 9PL, U.K.

[3]Laboratoire AIM, CEA/DSM - CNRS - Université Paris Diderot, DAPNIA/SAp, 91191 Gif sur Yvette, France

[4]Physics and Astronomy Dept., University of Western Ontario, London ON N6A 3K7, Canada

[5]Institute for Astronomy and Space Physics, Box 515, 75120 Uppsala, Sweden

Context: Red supergiant (RSG) stars exhibit significant mass loss by means of a slow, dense wind. They are often considered to be the more massive counterparts of Asymptotic Giant Branch (AGB) stars. While AGB mass loss is related to their strong pulsations, the RSG are often only weakly variable. This raises the question of whether their wind-driving mechanism and the dust composition of the wind are the same.
Aims: We study the conditions at the base of the wind by determining the dust composition of a sample of RSG. The dust composition is assumed to be sensitive to the density, temperature, and acceleration at the base of the wind. We compare the derived dust composition with the composition measured in AGB star winds.
Method: We compile a sample of 27 RSG infrared spectra (ISO-SWS) and supplement these with photometric measurements to derive the full spectral energy distribution (SED). These data are modelled using a dust radiative-transfer code, taking into account the optical properties of the relevant candidate materials to search for correlations between mass-loss rate, density at the inner edge of the dust shell, and stellar parameters.
Results: We find strong correlations between the dust composition, mass-loss rate, and the stellar luminosity, roughly in agreement with the theoretical dust condensation sequence. We identify the need for a continuous (near-)IR dust opacity and tentatively propose amorphous carbon, and we note significant differences with AGB star winds in terms of the presence of PAHs, absence of 'the' 13 μm band, and a lack of strong water bands.
Conclusions: Dust condensation in RSG is found to experience a freeze-out process that is similar to that in AGB stars. Together with the positive effect of the stellar luminosity on the mass-loss rate, this suggests that radiation pressure on dust grains is an important ingredient in the driving mechanism. Still, differences with AGB stars are manifold and thus the winds of RSG should be studied individually in further detail.

Accepted for publication in Astronomy & Astrophysics
Available from arXiv:0901.1262

Long-Period Variability in o Ceti

Matthew Templeton[1] *and Margarita Karovska*[2]

[1]AAVSO, 49 Bay State Road, Cambridge, MA 02138, USA

[2]Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138, USA

We carried out a new and sensitive search for long-period variability in the prototype of the Mira class of long-period pulsating variables, o Ceti (Mira A), the closest and brightest Mira variable. We conducted this search using an unbroken light curve from 1902 to the present, assembled from the visual data archives of five major variable star observing organizations from around the world. We applied several time-series analysis techniques to search for two specific kinds of variability: long secondary periods (LSPs) longer than the dominant pulsation period of ~ 333 days, and long-term period variation in the dominant pulsation period itself. The data quality is sufficient to detect coherent periodic variations with photometric amplitudes of 0.05 mag or less. We do not find evidence for coherent LSPs in o Ceti to a limit of 0.1 mag, where the amplitude limit is set by intrinsic, stochastic, low-frequency variability of approximately 0.1 mag. We marginally detect a slight modulation of the pulsation period similar in timescale to that observed in the Miras with meandering periods, but with a much lower period amplitude of ± 2 days. However, we do find clear evidence of a low-frequency power-law component in the Fourier spectrum of o Ceti's long-term light curve. The amplitude of this stochastic variability is approximately 0.1 mag at a period of 1000 days, and it exhibits a turnover for periods longer than this. This spectrum is similar to the red noise spectra observed in red supergiants.

Published in Astrophysical Journal 691, 1470 (2009)
Available from arXiv:0902.3604

Survey of Planetary Nebulae at 30 GHz with OCRA-p

B.M. Pazderska[1], *M.P. Gawroński*[1], *R. Feiler*[1], *M. Birkinshaw*[3], *I.W.A. Browne*[2], *R. Davis*[2], *A.J. Kus*[1], *K. Lancaster*[3], *S.R. Lowe*[2], *E. Pazderski*[1], *M. Peel*[2] *and P.N. Wilkinson*[2]

[1]Toruń Centre for Astronomy, Nicolaus Copernicus University, 87-100 Toruń/Piwnice, Poland

[2]Jodrell Bank Centre for Astrophysics, University of Manchester, Manchester, M13 9PL, UK

[3]University of Bristol, Tyndall Avenue, Bristol BS8 ITL, UK

We report the results of a survey of 442 planetary nebulae at 30 GHz. The purpose of the survey is to develop a list of planetary nebulae as calibration sources which could be used for high frequency calibration in future. For 41 PNe with sufficient data, we test the emission mechanisms in order to evaluate whether or not spinning dust plays an important role in their spectra at 30 GHz. The 30-GHz data were obtained with a twin-beam differencing radiometer, OCRA-p, which is in operation on the Torun 32-m telescope. Sources were scanned both in right ascension and declination. We estimated flux densities at 30 GHz using a free-free emission model and compared it with our data. The primary result is a catalogue containing the flux densities of 93 planetary nebulae at 30 GHz. Sources with sufficient data were compared with a spectral model of free-free emission. The model shows that free-free emission can generally explain the observed flux densities at 30 GHz thus no other emission mechanism is needed to account for the high frequency spectra.

Accepted for publication in A&A
Available from arXiv:0902.3945

How semiregular are irregular variables?

Thomas Lebzelter[1] *and Marlene Obbrugger*[1]

[1]Department of Astronomy, University of Vienna, Austria

We investigate the question whether there is a real difference in the light change between stars classified as semiregular (SRV) or irregular (Lb) variables by analysing photometric light curves of 12 representatives of each class. Using Fourier analysis we try to find a periodic signal in each light curve and determine the S/N of this signal. For all stars, independent of their variability class we detect a period above the significance threshold. No difference in the measured S/N between the two classes could be found. We propose that the Lb stars can be seen as an extension of the SRVs towards shorter periods and smaller amplitudes. This is in agreement with findings from other quantities which also showed no marked difference between the two classes.

Accepted for publication in AN
Available from arXiv:0902.4096

Circumstellar water vapour in M-type AGB stars: Constraints from $H_2O(1_{10}–1_{01})$ lines obtained with Odin

M. Maercker[1], *F.L. Schöier*[2], *H. Olofsson*[1,2], *P. Bergman*[3], *U. Frisk*[4], *Å. Hjalmarson*[2], *K. Justtanont*[2], *S. Kwok*[5,6], *B. Larsson*[1], *M. Olberg*[2] *and Aa. Sandqvist*[1]

[1]Stockholm University, AlbaNova University Center, Department of Astronomy, 10691 Stockholm, Sweden

[2]Onsala Space Observatory, 43992 Onsala, Sweden

[3]European Southern Observatory, Casila 19001, Santiago 19, Chile

[4]Swedish Space Corporation, PO Box 4207, 17104 Solna, Sweden

[5]Department of Physics & Astronomy, University of Calgary, Calgary, Canada

[6]Department of Physics, University of Hong Kong, Hong Kong

Context: A detailed radiative transfer code has been previously used to model circumstellar ortho-H_2O line emission

towards six M-type asymptotic giant branch stars using Infrared Space Observatory Long Wavelength Spectrometer data. Collisional and radiative excitation, including the $\nu_2 = 1$ state, was considered.
Aims: Spectrally resolved circumstellar $H_2O(1_{10}–1_{01})$ lines have been obtained towards three M-type AGB stars using the Odin satellite. This provides additional strong constrains on the properties of circumstellar H_2O, in particular on the chemistry in the stellar atmosphere, and the photodissociation in the outer envelope.
Methods: Infrared Space Observatory and Odin satellite H_2O line data are used as constraints for radiative transfer models. Special consideration is taken to the spectrally resolved Odin line profiles, and the effect of excitation to the first excited vibrational states of the stretching modes ($\nu_1 = 1$ and $\nu_3 = 1$) on the derived abundances is estimated. A non-local, radiative transfer code based on the accelerated lambda iteration formalism is used. A statistical analysis is performed to determine the best-fit models.
Results: The H_2O abundance estimates are in agreement with previous estimates. The inclusion of the Odin data sets stronger constraints on the size of the H_2O envelope. The $H_2O(1_{10}–1_{01})$ line profiles require a significant reduction in expansion velocity compared to the terminal gas expansion velocity determined in models of CO radio line emission, indicating that the H_2O emission lines probe a region where the wind is still being accelerated. Including the $\nu_3 = 1$ state significantly lowers the estimated abundances for the low-mass-loss-rate objects. This shows the importance of detailed modelling, in particular the details of the infrared spectrum in the range 3 to 6 μm, to estimate accurate circumstellar H_2O abundances.
Conclusions: Spectrally resolved circumstellar H_2O emission lines are important probes of the physics and chemistry in the inner regions of circumstellar envelopes around asymptotic giant branch stars. Predictions for H_2O emission lines in the spectral range of the upcoming Herschel/HIFI mission indicate that these observations will be very important in this context.

Published in Astronomy & Astrophysics

Precessing planetary magnetospheres in AGB stars? First detection of quasi-periodic polarization fluctuations in R Leo and V Cam

H.W. Wiesemeyer[1,2], *C. Thum*[1], *A. Baudry*[3,4] *and F. Herpin*[3,4]

[1]Institut de Radioastronomie Millimètrique, Grenoble, France
[2]Instituto de Radio Astronomía Milimétrica, Granada, Spain
[3]Laboratoire d'Astrophysique, Université de Bordeaux, France
[4]CNRS/INSU, UMR 5804, Floirac, France

The origin of magnetism around AGB stars is uncertain. These stars may drive an important dynamo, but if the magnetic energy dissipates all in X-rays, the observed X-ray luminosities are too low for a strong, dynamically important global field. Other explanations for the circular polarization of SiO masers in the atmospheres may thus be needed. The interaction of the AGB wind with previously ejected matter and with planets bears complex magneto-hydrodynamic phenomena on a short time scale, such that strong magnetic fields can be maintained locally. Here we provide observational evidence for the corresponding magnetic fluctuations. We trace magnetic activity with the circular polarization of the $v = 1$, $J = 2–1$ SiO masers, using a correlation polarimeter. In V Cam and R Leo, we find evidence of pseudo-periodic fluctuations of the circular polarization on a timescale of a few hours, from which we infer magnetic fluctuations of ~ 1 G. The phenomenon is rare and restricted to a narrow range of velocities. It seems to be associated with planetary wake flows suggested by VLBI maps. While scenarios involving magnetic activity in the extended stellar atmosphere have problems to explain all observed features, precessing Jovian magnetospheres predict all of them. For the case of R Leo, we constrain the orbit of the planet (estimated period 5.2 years) and estimate a stellar mass of 0.7 $M_\odot$.

Accepted for publication in Astronomy & Astrophysics
Available from arXiv:0809.0359

Pre-maximum spectro-imaging of the Mira star T Lep with AMBER/VLTI

J.-B. Le Bouquin[1], S. Lacour[2], S. Renard[2], E. Thiébaut[3], A. Merand[1] and T. Verhoelst[4]

[1]European Southern Observatory, Casilla 19001, Santiago 19, Chile

[2]LAOG–UMR 5571, CNRS and Université Joseph Fourier, BP 53, F-38041 Grenoble, France

[3]AIRI/Observatoire de Lyon, France and Jean-Marie Mariotti Center, France

[4]Instituut voor Sterrenkunde, KU Leuven, Celestijnenlaan 200D B-3001 Leuven, Belgium

Diffuse envelopes around Mira variables are among the most important sources influencing the chemical evolution of galaxies. However they represent an observational challenge because of their complex spectral features and their rapid temporal variability. We aimed at constraining the exact brightness distribution of the Mira star T Lep with a model-independent analysis. We obtained single-epoch interferometric observations with a dataset continuous in the spectral domain ($\lambda = 1.5$–2.4 μm) and in the spatial domain (interferometric baselines ranging from 11 to 96 m). We performed a model independent image reconstruction for each spectral bin using the MIRA software. We completed the analysis by modeling the data with a simple star+layer model inspired from the images. Reconstructed images confirm the general picture of a central star partially obscured by the surrounding molecular shell of changing opacity. At 1.7 μm, the shell becomes optically thin, with corresponding emission appearing as a ring circling the star. This is the first direct evidence of the spherical morphology of the molecular shell. Model fitting confirmed a spherical layer of constant size and changing opacity over the wavelengths. Rough modeling points to a continuum opacity within the shell, in addition to the CO and H_2O features. Accordingly, it appeared impossible to model the data by a photosphere alone in any of the spectral bins.

Accepted for publication in Astronomy and Astrophysics
Available from arXiv:0902.3698
and from http://hal.archives-ouvertes.fr/hal-00362232/en/

Double radio peak and non-thermal collimated ejecta in RS Ophiuchi following the 2006 outburst

S. P. S. Eyres[1], T. J. O'Brien[2], R. Beswick[2], T. W. B. Muxlow[2], G. C. Anupama[3], N. G. Kantharia[4], M. F. Bode[5], M. P. Gawroński[6], R. Feiler[6], A. Evans[7], M. T. Rushton[1], R. J. Davis[2], T. Prabhu[3], R. Porcas[8] and B. J. M. Hassall[1]

[1]Jeremiah Horrocks Institute, University of Central Lancashire, UK

[2]Jodrell Bank Centre for Astrophysics, The University of Manchester, Manchester, UK

[3]Indian Institute of Astrophysics, India

[4]National Centre for Radio Astrophysics, Tata Institute of Fundamental Research, India

[5]Astrophysics Research Institute, Liverpool John Moores University, UK

[6]Toruń Centre for Astronomy, Nicolas Copernicus University, Poland

[7]Astrophysics Group, Keele University, UK

[8]Max-Planck-Institut für Radioastronomie, Germany

We report MERLIN, VLA, OCRA-p, VLBA, Effelsberg and GMRT observations beginning 4.5 days after the discovery of RS Ophiuchi undergoing its 2006 recurrent nova outburst. Observations over the first 9 weeks are included, enabling us to follow spectral development throughout the three phases of the remnant development. We see dramatic brightening on days 4 to 7 at 6 GHz and an accompanying increase in other bands, particularly 1.46 GHz, consistent with transition from the initial "free expansion" phase to the adiabatic expansion phase. This is complete by day 13 when the flux density at 5 GHz is apparently declining from an unexpectedly early maximum (compared with expectations from observations of the 1985 outburst). The flux density recovered to a second peak by approximately day 40, consistent with behaviour observed in 1985. At all times the spectral index is consistent with mixed non-thermal and thermal emission. The spectral indices are consistent with a non-thermal component at lower frequencies on all dates, and the spectral index changes show that the two components are clearly variable. The estimated extent of the emission at 22 GHz on day 59 is consistent with the extended east and west features seen at 1.7 GHz with the VLBA

on day 63 being entirely non-thermal. We suggest a two-component model, consisting of a decelerating shell seen in mixed thermal and non-thermal emission plus faster bipolar ejecta generating the non-thermal emission, as seen in contemporaneous VLBA observations. Our estimated ejecta mass of $4{\pm}2{\times}10^{-7}$ M$_\odot$ is consistent with a WD mass of 1.4 M$_\odot$. It may be that this ejecta mass estimate is a lower limit, in which case a lower WD mass would be consistent with the data.

Accepted for publication in MNRAS
Available from arXiv:0902.2265

Spectroscopic confirmation of the planetary nebula nature of PM 1-242, PM 1-318 and PM 1-333 and morphological analysis of the nebulae

L. F. Miranda[1], *C. B. Pereira*[2] *and M. A. Guerrero*[1]

[1]Instituto de Astrofísica de Andalucia-CSIC, Granada, Spain

[2]Observatorio Nacional-MCT, Rio de Janeiro, Brasil

We present intermediate resolution long-slit spectra and narrow-band Hα, [N II] and [O III] images of PM 1-242, PM 1-318 and PM 1-333, three IRAS sources classified as possible planetary nebulae. The spectra show that the three objects are true planetary nebulae and allow us to study their physical properties; the images provide a detailed view of their morphology. PM 1-242 is a medium-to-high-excitation (e.g., He IIλ4686/H$\beta \sim 0.4$; [N II]λ6584/H$\alpha \sim 0.3$) planetary nebula with an elliptical shape containing [N II] enhanced point-symmetric arcs. An electron temperature [T$_e$([S III])] of $\sim$ 10250 K and an electron density [N$_e$([S II])] of $\sim$ 2300 cm^{-3} are derived for PM 1-242. Abundance calculations suggest a large helium abundance (He/H $\sim$ 0.29) in PM 1-242. PM 1-318 is a high-excitation (He IIλ4686/H$\beta \sim$ 1) planetary nebula with a ring-like inner shell containing two enhanced opposite regions, surrounded by a fainter round attached shell brighter in the light of [O III]. PM 1-333 is an extended planetary nebula with a high-excitation (He IIλ4686/Hβ up to $\sim$ 0.9) patchy circular main body containing two low-excitation knotty arcs. A low N$_e$([S II]) of $\sim$ 450 cm^{-3} and T$_e$([O III]) of $\sim$ 15000 K are derived for this nebula. Abundance calculations suggest that PM 1-333 is a type I planetary nebula. The lack of a sharp shell morphology, low electron density, and high-excitation strongly suggest that PM 1-333 is an evolved planetary nebula. PM 1-333 also shows two low-ionization polar structures whose morphology and emission properties are reminiscent of collimated outflows. We compare PM 1-333 with other evolved planetary nebulae with collimated outflows and find that outflows among evolved planetary nebulae exhibit a large variety of properties, in accordance with these observed in younger planetary nebula.

Accepted for publication in The Astronomical Journal

Conference Papers

Virtual Observatory studies of Planetary Nebulae

R.P. Mignani [1], *F. Kerber*[2], *R.L. Smart*[3], *D. Vande Putte*[1], *A. Wicenec*[2], *T. Rauch*[4], *H.M. Adorf*[5] *and R. Harrison*[6]

[1]UCL-MSSL, UK

[2]ESO, Germany

[3]INAF, Italy

[4]U. Tübingen, Germany

[5]MPA, Germany

[6]Rosebury School, UK

Starting from the Strasbourg ESO Catalogue (SEC) of Planetary Nebulae (PNe), the largest PNe compilation available with $\sim$ 1500 objects, we undertook a comprehensive study of the whole PN population, never carried out so far, only using on-line catalogues and data from public imaging surveys. The study includes the PN dynamics through their measured proper motions (PMs), the study of their galactocentric orbits, the study of their interactions with the interstellar medium (ISM), and the study of their UV-to-IR spectral energy distribution (SED). As a preliminary step required to perform cross-correlations with on-line catalogues, we first went through a systematic reassessment of the PN coordinates (Kerber et al. 2003a).

Poster contribution, published in "Multiwavelength Astronomy and the Virtual Observatory", held at ESAC-Madrid, December 1–3, 2008
Available from arXiv:0902.0960

The Physical Properties of Red Supergiants

Emily M. Levesque[1]

[1]Institute for Astronomy, University of Hawaii, 2680 Woodlawn Dr., Honolulu, HI 96822, USA

Red supergiants (RSGs) are a He-burning phase in the evolution of moderately massive stars (10–25 $M_\odot$). For many years, the assumed physical properties of these stars placed them at odds with the predictions of evolutionary theory. We have recently determined new effective temperatures and luminosities for the RSG populations of galaxies with a factor of ~ 8 range in metallicity, including the Milky Way, the Magellanic Clouds, and M 31. We find that these new physical properties greatly improve the agreement between the RSGs and the evolutionary tracks, although there are still notable difficulties with modeling the physical properties of RSGs at low metallicity. We have also examined several unusual RSGs, including VY CMa in the Milky Way, WOH G64 in the LMC, and a sample of four RSGs in the Magellanic Clouds that show considerable variations in their physical parameters, most notably their effective temperatures. For all of these stars we reexamine their placement on the H-R diagram, where they have appeared to occupy the "forbidden" region to the right of the Hayashi track. We have updated current understanding of the physical properties of VY CMa and WOH G64; in the case of the unusual Magellanic Cloud variables, we conclude that these stars are undergoing an unstable evolutionary phase not previously associated with RSGs.

Oral contribution, published in "Hot and Cool: Bridging Gaps in Massive Star Evolution"
Available from arXiv:0902.2789

CHARA/MIRC interferometry of red supergiants: diameters, effective temperatures and surface features

L.L. Kiss[1], *J.D. Monnier*[2], *T.R. Bedding*[1], *P. Tuthill*[1], *M. Zhao*[2], *M.J. Ireland*[1] *and T.A. ten Brummelaar*[3]

[1]Sydney Institute for Astrophysics, School of Physics, University of New South Wales, Australia

[2]Department of Astronomy, Univ. of Michigan at Ann Arbour, USA

[3]The CHARA Array, Georgia State University, USA

We have obtained H-band interferometric observations of three galactic red supergiant stars using the MIRC instrument on the CHARA array. The targets include AZ Cyg, a field RSG and two members of the Per OB1 association, RS Per and T Per. We find evidence of departures from circular symmetry in all cases, which can be modelled with the presence of hotspots. This is the first detection of these features in the H-band. The measured mean diameters and the spectral energy distributions were combined to determine effective temperatures. The results give further support to the recently derived hotter temperature scale of red supergiant stars by Levesque et al. (2005), which has been evoked to reconcile the empirically determined physical parameters and stellar evolutionary theories. We see a possible correlation between spottedness and mid-IR emission of the circumstellar dust, suggesting a connection between mass-loss and the mechanism that generates the spots.

Oral contribution, published in "Hot and Cool: Bridging Gaps in Massive Star Evolution", NASA Herschel Science Center, Nov. 10–12, 2008
Available from arXiv:0902.2602

Organic matter in space: from star dust to the Solar System

S. Kwok[1]

[1]University of Hong Kong, China

Organic compounds of high degree of complexity are now known to be widespread in the Universe, ranging from objects in our solar system to distant galaxies. Through the techniques of millimeter-wave spectroscopy, over 140 molecules have been identified through their rotational transitions. Space infrared spectroscopy has detected the stretching and bending modes of compounds with aromatic and aliphatic structures. Analyses of samples of meteorites, comets, asteroids, and interplanetary dust also revealed a rich content of organic substances, some of which could be of extra-solar origin. We review the current state of understanding of the origin, evolution, nature, and distribution of organic matter in space. Also discussed are a number of unexplained astronomical phenomena whose origins could be traced to organic carriers.

Published in Astrophysics and Space Science (invited review), 2009
Available from http://sal.physics.hku.hk/~kwok/publication_reprint/Reprints.htm

A Review of AGB Mass Loss Imaging Techniques

Massimo Marengo[1]

[1]Harvard-Smithsonian Center for Astrophysics, USA

Circumstellar imaging, across the electromagnetic spectrum, allows to derive fundamental diagnostics for the physics of mass loss in the AGB phase. I review the current status of the field, with particular emphasis on the techniques that provide the strongest constraints for mass loss modeling efforts.

Published in Publications of the Astronomical Society of Australia
Available from arXiv:0902.1536

The Origin and Shaping of Planetary Nebulae: Putting the Binary Hypothesis to the Test

Orsola De Marco[1]

[1]American Museum of Natural History, USA

Planetary nebulae (PNe) are circumstellar gas ejected during an intense mass-losing phase in the the lives of asymptotic giant branch stars. PNe have a stunning variety of shapes, most of which are not spherically symmetric. The debate over what makes and shapes the circumstellar gas of these evolved, intermediate mass stars has raged for two decades. Today the community is reaching a consensus that single stars cannot trivially manufacture PNe and impart to them non spherical shapes and that a binary companion, possibly even a sub-stellar one, might be needed in a majority of cases. This theoretical conjecture has however not been tested observationally. In this review we discuss the problem both from the theoretical and observational standpoints, explaining the obstacles that stand in the way of a clean observational test and ways to ameliorate the situation. We also discuss indirect tests of this hypothesis and its implications for stellar and galactic astrophysics.

Published in PASP Reviews
Available from arXiv:0902.1137

IR and sub-mm spectroscopy: A new tool for studying stellar evolution

Special Session 1 at IAU General Assembly, Rio de Janeiro, Aug. 3rd–6th, 2009

Infrared astronomy has come into its own over the last decade. Based on mature detector technology and sophisticated instrumentation it is contributing exciting science in many fields of astrophysics. Stellar evolution is a field that has long been dominated by ultraviolet and optical work but one that has benefited from a strongly increasing contribution from the infrared (IR) and sub-millimeter (sub-mm) domains. In particular, spectroscopy in these domains holds the promise to enable important advances through quantitative analysis of individual stars and stellar systems, and extending them to the earlier, dusty phases. All facets of stellar evolution, from star formation to advanced stages of stellar evolution will be impacted by the higher sensitivity and fidelity of the new spectral observations. The analysis of spectral lines leads to the determination of physical parameters of stars and their environments, including the determination of densities, effective temperatures, chemical composition, velocity flows, magnetic fields and excitation mechanisms.

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⋆ Proto-stars and the formation of multiple star systems
⋆ Formation of proto-planetary and debris disks
⋆ Massive star properties and winds
⋆ Probing stellar outer envelopes for mass loss in AGB stars
⋆ Velocity fields for mass outflows and jets from young stars and eruptive variables
⋆ Tests of stellar nucleosynthesis using post-main sequence stars
⋆ Chemical composition studies for cool stars, cold gas, and high excitation, low density plasmas
⋆ Stellar magnetic fields from magnetically sensitive IR spectral lines
⋆ Chemistry and kinematics of red giants and supergiants in metal-rich stellar clusters and galaxy fields

This Special Session aims to foster collaboration between various fields and bring together experts from theoretical and observational astrophysics, instrumentation and laboratory spectroscopy. In combination, these fields hold the key for the scientific success of the current and planned facilities. New observations will foster new thinking about old problems and will no doubt lead to transformative thinking for stellar evolution.

Abstracts for oral and poster contributions are submitted through the IAU Abstract Server through 15 March.

See also http://www.eso.org/sci/meetings/iau2009-sps1