THE AGB NEWSLETTER

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Editors: Jacco van Loon and Albert Zijlstra

Editorial

Dear Colleagues,

It is a pleasure to present you the 178$^{\rm th}$ issue of the AGB Newsletter.

We would like to draw your attention to the call for additional information on the enigmatic WISE object described in Ghandi et al. and the announcement at the back of this issue of the newsletter. This is a truly fascinating object, and could be a key to unlock the secrets behind the strange quirks that AGB star display.

Please also encourage your brilliant, motivated students to apply for the Ph.D. studentship to work with Professor Leen Decin in Leuven.

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

Editorially Yours,
Jacco van Loon and Albert Zijlstra

Food for Thought

This month's thought-provoking statement is:

Whether a Planetary Nebula forms depends on the timing of the last thermal pulse

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

Refereed Journal Papers

The role of super-AGB ejecta in the abundance patterns of multiple populations in globular clusters

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Star formation from matter including the hot CNO processed ejecta of asymptotic giant branch (AGB) winds is regarded as a plausible scenario to account for the chemical composition of a stellar second generation (SG) in Globular Clusters (GCs). The chemical evolution models, based on this hypothesis, so far included only the yields available for the massive AGB stars, while the possible role of super-AGB ejecta was either extrapolated or not considered. In this work, we explore in detail the role of super-AGB ejecta on the formation of the SG abundance patterns using yields recently calculated by Ventura and D'Antona. An application of the model to clusters showing extended N–O anticorrelations, like NGC 2808, indicates that a SG formation history similar to that outlined in our previous work is required: formation of an Extreme population with very large helium content from the pure ejecta of super-AGB stars, followed by formation of an Intermediate population by dilution of massive AGB ejecta with pristine gas. The present models are able to account for the very O-poor Na-rich Extreme stars once deep-mixing is assumed in SG giants forming in a gas with helium abundance $Y > 0.34$, which significantly reduces the atmospheric oxygen content, while preserving the sodium abundance. On the other hand, for clusters showing a mild O–Na anticorrelation, like M 4, the use of the new yields broadens the range of SG formation routes leading to abundance patterns consistent with observations. Specifically, our study shows that a model in which SG stars form only from super-AGB ejecta promptly diluted with pristine gas can reproduce the observed patterns. We briefly discuss the variety of (small) helium variations occurring in this model and its relevance for the horizontal branch morphology. In some of these models, the duration of the SG formation episode can be as short as $\sim$ 10 Myr; the formation time of the SG is therefore compatible with the survival of a cooling flow in the cluster core, previous to the explosion of the SG core collapse supernovae. We also explore models characterized by the formation of multiple populations in individual bursts, each lasting no longer than $\sim$ 10 Myr each.

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2D Monte-Carlo Radiative transfer modeling of the disk shaped secondary of ϵ Aurigae

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We present two dimensional Monte-Carlo radiative transfer models for the disk of the eclipsing binary ϵ Aur by fitting its spectral energy distribution from optical to the far-IR wavelengths. We also report new observations of ϵ Aur made by AKARI in its five mid and far-IR photometric bands and were used to construct our SED. The disk is optically thick and has flared disk geometry containing gas and dust with a gas to dust mass ratio of 100. We have taken the primary of the binary to be a F0Iae-type post-AGB star and the disk is heated by a B5V hot star with a temperature of 15,000 K at the center of the disk. We take the radius of the disk to be 3.8 AU for our models as constrained from the IR interferometric imaging observations of the eclipsing disk. Our models imply that the disk contains grains which

are much bigger than the ISM grains (grain sizes 10 μm to 100 μm). The grain chemistry of the disk is carbonaceous and our models show that silicate and ISM dust chemistry do not reproduce the slope of the observed SED in the mid-IR to far-IR regions. This implies that the formation of the disk shaped secondary in ϵ Aur system could be the result of accretion of matter and or mass transfer from the primary which is now a F0Iae post-AGB star. It is not a proto-planetary disk. The disk is seen nearly edge on with an inclination angle larger than 85°. We propose from our radiative transfer modeling that the disk is not solid and have a void of 2AU radius at the center within which no grains are present making the region nearly transparent. The disk is not massive, its mass is derived to be less than 0.005 $M_\odot$.

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Strong ^{13}CO $J = 3 \rightarrow 2$ line in IRAS 16342−3814: Evidence for the Hot-Bottom Burning

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We observed four "water fountain" sources in the CO $J = 3 - -2$ line emission with the Atacama Submillimeter Telescope Experiment (ASTE) 10-m telescope in 2010–2011. The water fountain sources are evolved stars that form high-velocity collimated jets traced by H_2O maser emission. The CO line was detected only from IRAS 16342−3814. The present work confirmed that the ^{12}CO to ^{13}CO line intensity ratio is ~ 1.5 at the systemic velocity. We discuss the origins of the very low ^{12}CO to ^{13}CO intensity ratio, as possible evidence for the "hot-bottom burning" in an oxygen-rich star, and the CO intensity variation in IRAS 16342−3814.

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Time resolved spectroscopy of BD +46° 442: gas streams and jet creation in a newly discovered evolved binary with a disk

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Previous studies have shown that many post-AGB stars with dusty disks are associated with single-lined binary stars. To verify the binarity hypothesis on a larger sample, we started a high-resolution spectral monitoring of about 40 field giants, whose binarity was suspected based on either a light curve, an infrared excess, or a peculiar chemical composition. Here we report on the discovery of the periodic RV variations in BD +46° 442, a high-latitude F giant with a disk. We interpret the variations due to the motion around a faint companion, and deduce the following orbital parameters: $P_{\rm orb} = 140.77$ d, $e = 0.083$, $a \sin i = 0.31$ AU. We find it to be a moderately metal-poor star ([M/H] = −0.7) without a strong depletion pattern in the photospheric abundances. Interestingly, many lines show periodic changes with the orbital phase: Hα switches between a double-peak emission and a P Cyg-like profiles, while strong metal lines appear split during the maximum redshift. Similar effects are likely visible in the spectra of other

post-AGB binaries, but their regularity is not always realized due to sporadic observations. We propose that these features result from an ongoing mass transfer from the evolved giant to the companion. In particular, the blue-shifted absorption in Hα, which occurs only at superior conjunction, may result from a jet originating in the accretion disk around the companion and seen in absorption towards the luminous primary.

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Abundances of neutron-capture elements in G 24-25. A halo-population CH subgiant

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The differences between the neutron-capture element abundances of halo stars are important to our understanding of the nucleosynthesis of elements heavier than the iron group. We present a detailed abundance analysis of carbon and twelve neutron-capture elements from Sr up to Pb for a peculiar halo star G 24-25 with [Fe/H] = −1.4 in order to probe its origin. The equivalent widths of unblended lines are measured from high resolution NOT/FIES spectra and used to derive abundances based on *Kurucz* model atmospheres. In the case of CH, Pr, Eu, Gd, and Pb lines, the abundances are derived by fitting synthetic profiles to the observed spectra. Abundance analyses are performed both relative to the Sun and to a normal halo star G 16-20 that has similar stellar parameters as G 24-25. We find that G 24-25 is a halo subgiant star with an unseen component. It has large overabundances of carbon and heavy s-process elements and mild overabundances of Eu and light s-process elements. This abundance distribution is consistent with that of a typical CH giant. The abundance pattern can be explained by mass transfer from a former asymptotic giant branch component, which is now a white dwarf.

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The end of super-AGB and massive AGB stars I. The instabilities that determine the final mass of AGB stars

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The literature is rich in analysis and results related to thermally pulsing-asymptotic giant branch (TP-AGB) stars, but the problem of the instabilities that arise and cause the divergence of models during the late stages of their evolution is rarely addressed. We investigate the physical conditions, causes and consequences of the interruption in the calculations of massive AGB stars in the late thermally-pulsing AGB phase. We have thoroughly analysed the physical structure of a solar metallicity 8.5 $M_\odot$ star and described the physical conditions at the base of the convective envelope (BCE) just prior to divergence.
We find that the local opacity maximum caused by M-shell electrons of Fe-group elements lead to the accumulation of an energy excess, to the departure of thermal equilibrium conditions at the base of the convective envelope and,

eventually, to the divergence of the computed models. For the 8.5 $M_\odot$ case we present in this work the divergence occurs when the envelope mass is about 2 $M_\odot$. The remaining envelope masses range between somewhat less than 1 and more than 2 $M_\odot$ for stars with initial masses between 7 and 10 $M_\odot$ and, therefore, our results are relevant for the evolution and yields of super-AGB stars. If the envelope is ejected as a consequence of the instability we are considering, the occurrence of electron-capture supernovae would be avoided at solar metallicity.

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The geometry of the close environment of SV Psc as probed by VLTI/MIDI

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Context: SV Psc is an asymptotic giant branch (AGB) star surrounded by an oxygen-rich dust envelope. The mm-CO line profile of the object's outflow shows a clear double-component structure. Because of the high angular resolution, mid-IR interferometry may give strong constraints on the origin of this composite profile.
Aims: The aim of this work is to investigate the morphology of the environment around SV Psc using high-angular resolution interferometry observations in the mid-IR with the Very Large Telescope MID-infrared Interferometric instrument (VLTI/MIDI).
Methods: Interferometric data in the N-band taken at different baseline lengths (ranging from 32–64 m) and position angles (73–142°) allow a study of the morphology of the circumstellar environment close to the star. The data are interpreted on the basis of 2-dimensional, chromatic geometrical models using the fitting software tool GEM-FIND developed for this purpose.
Results: The results favor two scenarios: (i) the presence of a highly inclined, optically thin, dusty disk surrounding the central star; (ii) the presence of an unresolved binary companion at a separation of 13.7 AU and a position angle of 121.°8 NE. The derived orbital period of the binary is 38.1 yr. This detection is in good agreement with hydrodynamic simulations showing that a close companion could be responsible for the entrainment of the gas and dust into a circumbinary structure.

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Abundances of PNe in the outer disk of M 31

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We present spectroscopic observations and chemical abundances of 16 planetary nebulae (PNe) in the outer disk of M 31. The [O III] λ4363 line is detected in all objects, allowing a direct measurement of the nebular temperature essential for accurate abundance determinations. Our results show that the abundances in these M 31 PNe display the same correlations and general behaviors as Type II PNe in the Milky Way Galaxy. We also calculate photoionization models to derive estimates of central star properties. From these we infer that our sample PNe, all near the bright-end

cutoff of the Planetary Nebula Luminosity Function, originated from stars near 2 $M_{\odot}$. Finally, under the assumption that these PNe are located in M 31's disk, we plot the oxygen abundance gradient, which appears shallower than the gradient in the Milky Way.

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Gaseous material orbiting the polluted, dusty white dwarf HE 1349−2305

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We present new spectroscopic observations of the polluted, dusty, helium-dominated atmosphere white dwarf star HE 1349−2305. Optical spectroscopy reveals weak Ca II infrared triplet emission indicating that metallic gas debris orbits and is accreted by the white dwarf. Atmospheric abundances are measured for magnesium and silicon while upper limits for iron and oxygen are derived from the available optical spectroscopy. HE 1349−2305 is the first gas disk-hosting white dwarf star identified amongst previously known polluted white dwarfs. Further characterization of the parent body polluting this star will require ultraviolet spectroscopy.

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Mapping the linearly polarized spectral line emission around the evolved star IRC +10° 216

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We present spectro-polarimetric observations of several molecular lines obtained with the Submillimeter Array (SMA) toward the carbon rich AGB star IRC +10° 216. We have detected and mapped the linear polarization of the CO 3–2, SiS 19–18 and CS 7–6 lines. The polarization arises at a distance of $\simeq$ 450 AU from the star and is blueshifted with respect the Stokes I. The SiS 19–18 polarization pattern appears to be consistent with a locally radial magnetic field configuration. However, the CO 3–2 and CS 7–6 line polarization suggests an overall complex magnetic field morphology within the envelope. This work demonstrates the feasibility of using spectro-polarimetric observations to carry out tomographic imaging of the magnetic field in circumstellar envelopes.

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Spectral types of red supergiants in NGC 6822 and the Wolf–Lundmark–Melotte galaxy

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We present moderate-resolution spectroscopic observations of red supergiants (RSGs) in the low-metallicity Local Group galaxies NGC 6822 ($Z = 0.4$ $Z_\odot$) and Wolf–Lundmark–Melotte (WLM; $Z = 0.1$ $Z_\odot$). By combining these observations with reduction techniques for multislit data reduction and flux calibration, we are able to analyze spectroscopic data of 16 RSGs in NGC 6822 and spectrophotometric data of 11 RSGs in WLM. Using these observations we determine spectral types for these massive stars, comparing them to Milky Way and Magellanic Clouds RSGs and thus extending observational evidence of the abundance-dependent shift of RSG spectral types to lower metallicities. In addition, we have uncovered two RSGs with unusually late spectral types (J000158.14−152332.2 in WLM, with a spectral type of M3 I, and J194453.46−144552.6 in NGC 6822, with a spectral type of M4.5 I) and a third RSG (J194449.96−144333.5 in NGC 6822) whose spectral type has varied from a M2.5 in 1997 to a K5 in 2008. All three of these stars could potentially be members of a recently-discovered class of extreme RSG variables.

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Dramatic infrared variability of WISE J1810−3305: catching early-time dust ejection during the thermal pulse of an AGB star?

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We present the discovery of a source with broadband infrared photometric characteristics similar to Sakurai's Object. WISE J180956.27−330500.2 (hereafter, J1810−3305) shows very red *WISE* colors, but a very blue 2MASS [K] vs. *WISE* [W1 (3.4 μm)] color. It was not visible during the *IRAS* era, but now has a 12-μm flux well above the *IRAS* point source catalog detection limit. There are also indications of variability in historical optical photographic plates, as well as in multi-epoch *AKARI* mid-infrared measurements. The broadband infrared spectral energy distribution shape, post-*IRAS* brightening and multiwavelength variability are all characteristics also shared by Sakurai's Object – a post asymptotic giant branch (post-AGB) star which underwent a late thermal pulse and recently ejected massive envelopes of dust that are currently expanding and cooling. Optical progenitor colors suggest that J1810−3305 may have been of late spectral class. Its dramatic infrared brightening, and the detection of a late-type optical counterpart are consistent with a scenario in which we have caught an extremely massive dust ejection event (in 1998 or shortly before) during the thermal pulse of an AGB star, thus providing a unique opportunity to observe stellar evolution in this phase. J1810−3305 is the only source in the entire *WISE* preliminary data release with similar infrared SED and variability, emphasizing the rarity of such sources. Confirmation of its nature is of great importance.

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Resolving the electron temperature discrepancies in H II regions and Planetary Nebulae: κ-distributed electrons

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The measurement of electron temperatures and metallicities in H II regions and Planetary Nebulae (PNe) has – for several decades – presented a problem: results obtained using different techniques disagree. What is worse, they disagree consistently. There have been numerous attempts to explain these discrepancies, but none has provided a satisfactory solution to the problem. In this paper, we explore the possibility that electrons in H II regions and PNe depart from a Maxwell–Boltzmann equilibrium energy distribution. We adopt a "κ-distribution" for the electron energies. Such distributions are widely found in Solar System plasmas, where they can be directly measured. This simple assumption is able to explain the temperature and metallicity discrepancies in H II regions and PNe arising from the different measurement techniques. We find that the energy distribution does not need to depart dramatically from an equilibrium distribution. From an examination of data from H II regions and PNe it appears that $\kappa \gtrsim 10$ is sufficient to encompass nearly all objects. We argue that the κ-distribution offers an important new insight into the physics of gaseous nebulae, both in the Milky Way and elsewhere, and one that promises significantly more accurate estimates of temperature and metallicity in these regions.

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First evidence of globular cluster formation from the ejecta of prompt type Ia supernovae

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Recent spectroscopic observations of globular clusters (GCs) in the Large Magellanic Cloud (LMC) have discovered that one of the intermediate-age GC, NGC 1718 with [Fe/H] $= -0.7$ has an extremely low [Mg/Fe] ratio of ~ -0.9. We propose that NGC 1718 was formed from the ejecta of type Ia supernovae (SNe Ia) mixed with very metal-poor ([Fe/H] < -1.3) gas about ~ 2 Gyr ago. The proposed scenario is shown to be consistent with the observed abundances of Fe-group elements such as Cr, Mn, and Ni. In addition, compelling evidence for asymptotic giant branch stars playing a role in chemical enrichment during this GC formation is found. We suggest that the origin of the metal-poor gas is closely associated with the efficient gas-transfer from the outer gas disk of the Small Magellanic Cloud to the LMC disk. We anticipate that the outer part of the LMC disk contains field stars exhibiting significantly low [Mg/Fe] ratios, formed through the same process as NGC 1718.

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Molecular abundances in the inner layers of IRC +10° 216

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The inner layers of circumstellar envelopes around AGB stars are sites where a variety of processes such as thermochemical equilibrium, shocks induced by the stellar pulsation, and condensation of dust grains determine the chemical

composition of the material that is expelled into the outer envelope layers and, ultimately, into interstellar space. We aim at studying the abundances, throughout the whole circumstellar envelope of the carbon star IRC +10° 216, of several molecules formed in the inner layers in order to constrain the different processes at work in such regions. Observations towards IRC +10° 216 of CS, SiO, SiS, NaCl, KCl, AlCl, AlF, and NaCN have been carried out with the IRAM 30-m telescope in the 80–357.5 GHz frequency range. A large number of rotational transitions covering a wide range of energy levels, including highly excited vibrational states, are detected in emission and serve to trace different regions of the envelope. Radiative transfer calculations based on the LVG formalism have been performed to derive molecular abundances from the innermost out to the outer layers. The excitation calculations include infrared pumping to excited vibrational states and inelastic collisions, for which up-to-date rate coefficients for rotational and, in some cases, ro–vibrational transitions are used. We find that in the inner layers CS, SiO, and SiS have abundances relative to H_2 of 4×10^{-6}, 1.8×10^{-7}, and 3×10^{-6}, respectively, and that CS and SiS have significant lower abundances in the outer envelope, which implies that they actively contribute to the formation of dust. Moreover, in the inner layers, the amount of sulfur and silicon in gas phase molecules is only 27% for S and 5.6% for Si, implying that these elements have already condensed onto grains, most likely in the form of MgS and SiC. Metal-bearing molecules lock up a relatively small fraction of metals, although our results indicate that NaCl, KCl, AlCl, AlF, and NaCN, despite their refractory character, are not significantly depleted in the cold outer layers. In these regions a few percent of the metals Na, K, and Al survive in the gas phase, either in atomic or molecular form, and are therefore available to participate in the gas phase chemistry in the outer envelope.

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Herschel/HIFI observation of highly excited rotational lines of HNC toward IRC +10° 216

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We report the detection in emission of various highly excited rotational transitions of HNC ($J = 6-5$ through $J = 12-11$) toward the carbon-star envelope IRC +10° 216 using the HIFI instrument on-board the *Herschel* Space Observatory. Observations of the $J = 1-0$ and $J = 3-2$ lines of HNC with the IRAM 30-m telescope are also presented. The lines observed with HIFI have upper level energies corresponding to temperatures between 90 and 340 degrees Kelvin, and trace a warm and smaller circumstellar region than that seen in the interferometric maps of the $J = 1-0$ transition, whose emission extends up to a radius of $20''$. After a detailed chemical and radiative transfer modeling, we find that the presence of HNC in the circumstellar envelope of IRC +10° 216 is consistent with formation from the precursor ion $HCNH^+$, which in turn is produced through several proton transfer reactions which are triggered by the cosmic-ray ionization. We also find that the radiative pumping through λ21-μm photons to the first excited state of the bending mode ν_2 plays a crucial role to populate the high-J HNC levels involved in the transitions observed with HIFI. Emission in these high-J rotational transitions of HNC is expected to be strong in regions which are warm and dense and/or have an intense infrared flux at wavelengths around 21 μm.

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Discovery of multiple shells around the planetary nebula IC 418

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We have analysed optical, near-, and mid-IR images of the bright planetary nebula (PN) IC 418. These images probe unambiguously for the first time a number of low surface brightness structures and shells around the bright main nebula, including radial filaments or rays, a system of three concentric rings, and two detached haloes with sizes $\sim 150''$ and $220'' \times 250''$, respectively. The main nebula is slightly off-centered with respect to the elliptical outer halo. The time-lapse between the two haloes is 10,000–50,000 yr, whereas the time-lapse between the three concentric rings is ~ 630 yr. We emphasize the advantages of near- and mid-IR imaging for the detection of faint structures and shells around optically bright nebulae.

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Carbon-rich dust production in metal-poor galaxies in the Local Group

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We have observed a sample of 19 carbon stars in the Sculptor, Carina, Fornax, and Leo I dwarf spheroidal galaxies with the Infrared Spectrograph on the *Spitzer* Space Telescope. The spectra show significant quantities of dust around the carbon stars in Sculptor, Fornax, and Leo I, but little in Carina. Previous comparisons of carbon stars with similar pulsation properties in the Galaxy and the Magellanic Clouds revealed no evidence that metallicity affected the production of dust by carbon stars. However, the more metal-poor stars in the current sample appear to be generating less dust. These data extend two known trends to lower metallicities. In more metal-poor samples, the SiC dust emission weakens, while the acetylene absorption strengthens. The bolometric magnitudes and infrared spectral properties of the carbon stars in Fornax are consistent with metallicities more similar to carbon stars in the Magellanic Clouds than in the other dwarf spheroidals in our sample. A study of the carbon budget in these stars reinforces previous considerations that the dredge-up of sufficient quantities of carbon from the stellar cores may trigger the final superwind phase, ending a star's lifetime on the asymptotic giant branch.

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Conference Papers

Radio and IR interferometry of SiO maser stars

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Radio and infrared interferometry of SiO maser stars provide complementary information on the atmosphere and circumstellar environment at comparable spatial resolution. Here, we present the latest results on the atmospheric structure and the dust condensation region of AGB stars based on our recent infrared spectro-interferometric observations, which represent the environment of SiO masers. We discuss, as an example, new results from simultaneous VLTI and VLBA observations of the Mira variable AGB star R Cnc, including VLTI near- and mid-infrared interferometry, as well as VLBA observations of the SiO maser emission toward this source. We present preliminary results from a monitoring campaign of high-frequency SiO maser emission toward evolved stars obtained with the APEX telescope, which also serves as a precursor of ALMA images of the SiO emitting region. We speculate that large-scale long-period chaotic motion in the extended molecular atmosphere may be the physical reason for observed deviations from point symmetry of atmospheric molecular layers, and for the observed erratic variability of high-frequency SiO maser emission.

Oral contribution, published in IAU Symposium 287 "Cosmic masers – from OH to H_0", eds. R.S. Booth, E.M.L. Humphreys & W.H.T. Vlemmings (invited paper)
Available from arXiv:1204.3546

Photoionization models of the Eskimo nebula: evidence for a binary central star?

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The ionizing star of the planetary nebula NGC 2392 is too cool to explain the high excitation of the nebular shell, and an additional ionizing source is necessary. We use photoionization modeling to estimate the temperature and luminosity of the putative companion. Our results show it is likely to be a very hot ($T_{\rm eff} \sim 250$ kK), dense white dwarf. If the stars form a close binary, they may merge within a Hubble time, possibly producing a Type Ia supernova.

Poster contribution, published in IAU Symp. 282, p.470 (2012)
Available from arXiv:1204.5696
and from http://dx.doi.org/10.1017/S1743921311028134

Job Advert

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The Instituut voor Sterrenkunde of Leuven University has a vacancy for a 4-year PhD position entitled: 'The circumstellar environment of evolved stars as traced by molecules.'

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Application deadline is June 15, 2012

See also http://fys.kuleuven.be/ster/vacancies/phd-cs-environment-decin-2012

Announcement

Information Wanted: WISE J180956.27−330500.2

In our recent paper (Gandhi et al., see abstract in this issue), we report drastic infrared variability of WISE J180956.27 −330500.2 in the last 15 years, and consider the possibility that it is undergoing mass ejection following a thermal pulse. Unfortunately, little attention has been paid to this object in the past and the lack of observations (see Table 1 in the paper) makes the nature of this object still unclear.

Therefore we request your help and participation in our attempt to understand this fascinating object. If you have any information about this source, for example photometric measurements and/or images covering this field, please send us the data with observing date, filters, telescope, and name of the observer(s). Both past observations from your archive, or new observations made now are welcome. The data will be archived and made publicly available via the web.

Even a single photometric measurement may be a key to solving its mystery, when merged with other data.

Contact address: yamamura@ir.isas.jaxa.jp

Thank you in advance,
Issei Yamamura and Poshak Gandhi