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Editors: Jacco van Loon and Albert Zijlstra

Editorial

Dear Colleagues,

It is our pleasure to present you the 155th issue of the AGB Newsletter, featuring the first avalanche of results coming from the *Herschel Space Observatory*. Enjoy!

All the more reason to attend the AGB star conference in Vienna this Summer — early registration is still open, until 10 June.

Last month's "Food for Thought" generated one reaction — you might guess by whom: "How does one recognise an AGB star? It fails to converge!".

Because one of us is going on a brief vacation, the next issue is planned to be distributed on the 6th of July 2010.

Editorially Yours,
Jacco van Loon and Albert Zijlstra

Food for Thought

This month's thought-provoking statement is:

What do planets (and debris disks) -really- do to AGB stars?

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

Comparing shocks in planetary nebulae with the Solar wind termination shock

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We show that suprathermal particles, termed pick-up ions (PUIs), might reduce the postshock temperature of the fast wind and jets in some planetary nebulae (PNs) and in symbiotic systems. The goal is to explain the finding that the temperature of the “hot bubble” formed by the post-shock gas in some PNs and symbiotic nebulae is lower, sometimes by more than an order of magnitude, than the value expected from simple hydrodynamical calculations. Although various explanations have been proposed, there is as yet no prefered solution for this “low tempeature problem.” PUIs have been invoked to explain the low temperature behind the termination shock of the solar wind. While in the case of the solar wind the neutral atoms that turn into PUIs penetrate the pre-shock solar wind region from the interstellar medium (ISM), in PNs the PUI source is more likely slowly moving clumps embedded in the fast wind or jets. These clumps are formed by instabilities or from backflowing cold gas. Our estimates indicate that in young PNs these PUIs will thermalize before leaving the system. Only in older PNs whose sizes exceed ~ 5000 AU and for which the fast-wind mass-loss rate is $\dot{M}_{\rm w} \lesssim 10^{-7}$ $M_\odot$ yr^{-1} do we expect the PUIs to be an efficient carrier of energy out of the postshock region (the hot bubble).

Submitted to ApJ

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Fluorine abundances in Galactic Asymptotic Giant Branch stars

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An analysis of the fluorine abundance in Galactic AGB carbon stars (24 N-type, 5 SC-type, and 5 J-type) is presented. This study uses the state-of-the-art carbon rich atmosphere models and improved atomic and molecular line lists in the 2.3 μm region. Significantly lower F abundances are obtained in comparison to previous study in the literature. The main reason of this difference is due to molecular blends. In the case of carbon stars of SC-type, differences in the model atmospheres are also relevant. The new F enhancements are now in agreement with the most recent theoretical nucleosynthesis models in low-mass AGB stars, solving the long- standing problem of F in Galactic AGB stars. Nevertheless, some SC-type carbon stars still show larger F abundances than predicted by stellar models. The possibility that these stars are of larger mass is briefly discussed.

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A differential chemical abundance scale for the Globular Cluster M 5

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We present LTE chemical abundances for five red giants and one AGB star in the Galactic globular cluster (GC) M 5 based on high resolution spectroscopy using the MIKE spectrograph on the Magellan 6.5-m Clay telescope. Our results are based on a line-by-line differential abundance analysis relative to the well-studied red giant Arcturus. The stars in our sample that overlap with existing studies in the literature are consistent with published values for [Fe/H] and agree to within typically 0.04 dex for the α-elements. Most deviations can be assigned to varying analysis techniques in the literature. This strengthens our newly established differential GC abundance scale and advocates future use of this method. In particular, we confirm a mean [Fe I/H] of -1.33 ± 0.03 (stat.) ± 0.03 (sys.) dex and also reproduce M 5's enhancement in the α-elements (O, Mg, Si, Ca, Ti) at +0.4 dex, rendering M 5 a typical representative of the Galactic halo. Over-ionization of Fe I in the atmospheres of these stars by non-LTE effects is found to be less than 0.07 dex. Five of our six stars show O–Na–Al–Mg abundance patterns consistent with pollution by proton-capture nucleosynthesis products. (This paper includes data gathered with the 6.5 m Magellan Telescopes located at Las Campanas Observatory, Chile.)

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A statistical analysis of the late-type stellar content in the Andromeda halo

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We present a statistical characterization of the carbon-star to M-giant (C/M) ratio in the halo of M 31. Based on application of pseudo-filter band passes to our Keck/DEIMOS spectra we measure the (81–77)-color index of 1288 stars in the giant stellar stream and in halo fields out to large distances. From this well-established narrow-band system, supplemented by V–I colors, we find only a low number (five in total) of C-star candidates. The resulting low C/M ratio of 10% is consistent with the values in the M 31 disk and inner halo from the literature. Although our analysis is challenged by small number statistics and our sample selection, there is an indication that the oxygen-rich M-giants occur in similar number throughout the entire halo. We also find no difference in the C-star population of the halo fields compared to the giant stream. The very low C/M ratio is at odds with the observed low metallicities and the presence of intermediate-age stars at large radii. Our observed absence of a substantial carbon star population in the these regions indicates that the (outer) M 31 halo cannot be dominated by the debris of disk-like or SMC-type galaxies, but rather resemble the dwarf elliptical NGC 147.

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Dusty disks around white dwarfs I: Origin of debris disks

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A significant fraction of the mature FGK stars have cool dusty disks at least an orders of magnitudes brighter than the solar system's outer zodiacal light. Since such dusts must be continually replenished, they are generally assumed to be the collisional fragments of residual planetesimals analogous to the Kuiper Belt objects. At least 10% of solar

type stars also bear gas giant planets. The fraction of stars with known gas giants or detectable debris disks (or both) appears to increase with the stellar mass. Here, we examine the dynamical evolution of systems of long-period gas giant planets and residual planetesimals as their host stars evolve off the main sequence, lose mass, and form planetary nebula around remnant white dwarf cores. The orbits of distant gas giant planets and super-km-size planetesimals expand adiabatically. During the most intense AGB mass loss phase, sub-meter-size particles migrate toward their host stars due to the strong hydrodynamical drag by the intense stellar wind. Along their migration paths, gas giant planets capture and sweep up sub-km-size planetesimals onto their mean-motion resonances. These planetesimals also acquire modest eccentricities which are determined by the mass of the perturbing planets, the rate and speed of stellar mass loss. The swept-up planetesimals undergo disruptive collisions which lead to the production of grains with an extended size range. The radiation drag on these particles is ineffective against the planets' resonant barrier and they form 30-to-150-AU-sizes rings which can effective reprocess the stellar irradiation in the form of FIR continuum. We identify the recently discovered dust ring around the white dwarf WD 2226-210 at the center of the Helix nebula as a prototype of such disks and suggest such rings may be common.

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Are C-rich ultra iron poor stars also He-rich?

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The three most iron poor stars presently known ([Fe/H] equal to -5.96, -5.4 and -4.75) are carbon-rich, they are called C-Rich Ultra-Metal Poor Stars (CRUMPS). The origin of their peculiar surface abundances is not understood. We propose a synthetic view of the different models so far proposed to explain the peculiar abundances observed at the surface of the CRUMP stars. We deduce some expected trends based on nucleosynthetic arguments and look for signatures allowing to discriminate among models. We discuss the conditions for having CRUMP stars which are He-rich, i.e. with a mass fraction of helium greater than 0.30 and up to 0.60. We discuss the chemical composition of stars made of interstellar medium mixed with wind material of very metal poor massive stars, with wind plus supernova ejecta and with material extracted from the envelope of early AGB stars. Rotating and non-rotating models are considered. The high nitrogen abundances observed in CRUMP stars imply that the material which is responsible for their peculiar abundance pattern must be heavily enriched in primary nitrogen. We show that rotating stars (both massive and intermediate mass stars) can produce the required amount of primary nitrogen, and can also account for the observed enhancements in C, O, Na, Mg and Al. CRUMP stars formed from wind material of massive stars mixed with small amounts of pristine interstellar medium are He-rich (helium mass fraction between 0.30 and 0.60), Li-depleted and present low $^{12}C/^{13}C$ ratios (inferior to 10 in number). Such He-rich stars, if discovered, would confirm that the most metal poor CRUMPs formed from essentially pure wind/envelope material. They would provide the most direct way to probe the nucleosynthetic outputs of the first generations of stars. We show that rotation is a key ingredient to explain the abundance patterns of CRUMPS stars and probably also of at least some Carbon-Enhanced Metal Poor (CEMP) stars, in particuliar the CEMP-no stars. Similar non-rotating models, without any extra-mixing, do not succeed to explain the enhancements in the three CNO elements.

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Red-giant seismic properties analyzed with CoRoT

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The CoRoT 5-month long observation runs provide us with the opportunity to analyze a large variety of red-giant stars and derive their fundamental parameters from their asteroseismic properties. We perform an analysis of more than 4 600 CoRoT light curves to extract as much information as possible. We take into account the characteristics of both the star sample and the method to ensure that our asteroseismic results are as unbiased as possible. We also study and compare the properties of red giants in two opposite regions of the Galaxy. We analyze the time series using the envelope autocorrelation function to extract precise asteroseismic parameters with reliable error bars. We examine first the mean large frequency separation of solar-like oscillations and the frequency of the maximum seismic amplitude, then the parameters of the excess power envelope. With the additional information of the effective temperature, we derive the stellar mass and radius. We identify more than 1 800 red giants among the 4 600 light curves and obtain accurate distributions of the stellar parameters for about 930 targets. We are able to reliably measure the mass and radius of several hundred red giants. We derive precise information about the stellar population distribution and the red clump. By comparing the stars observed in two different fields, we find that the stellar asteroseismic properties are globally similar, but that the characteristics are different for red-clump stars. This study demonstrates the efficiency of statistical asteroseismology: validating scaling relations allows us to infer fundamental stellar parameters, derive precise information about red-giant evolution and interior structure, analyze and compare stellar populations from different fields.

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Nearby early-type galaxies with ionized gas. IV. Origin and powering mechanism of the ionized gas

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With the aim of constraining the source of excitation and the origin of the ionized gas in early-type galaxies (ETGs), we analyzed intermediate-resolution optical spectra of a sample of 65 ETGs mostly located in low density environments. Optical emission lines are detected in 89% of the sample. The incidence and strength of emission do not correlate either with the E/S0 classification, or with the fast/slow rotator classification. Comparing the nuclear $r < r_e/16$ line-emission with the classical [O III]/Hβ vs. [N II]/Hα diagnostic diagram, the galaxy activity is so classified: 72% of the galaxies with emission are LINERs, 9% are Seyferts, 12% are composite/transition objects, and 7% are non-classified. Seyferts have young luminosity-weighted ages (< 5 Gyr), and appear, on average, significantly younger than LINERs and composites. Excluding the Seyferts from our sample, we find that the spread in the ([O III], Hα, or [N II]) emission strength increases with the galaxy central velocity dispersion $sigma_c$. The [N II]/Hα ratio decreases with increasing galactocentric distance, indicating either a decrease of the nebular metallicity, or a progressive "softening" of the ionizing spectrum. The average oxygen abundance of the ionized gas is slightly less than solar, and a comparison with the results obtained in Paper III from Lick indices reveals that it is ~ 0.2 dex lower than that of stars. Conclusions: the nuclear emission can be explained with photoionization by PAGB stars alone only in $\sim 22\%$ of the LINER/composite sample. On the other hand, we can not exclude an important role of PAGB star photoionization at larger radii. For the major fraction of the sample, the nuclear emission is consistent with excitation by either a low-accretion rate AGN or fast shocks (200–500 km s^{-1}) in a relatively gas-poor environment ($n < 100$ cm^{-3}), or both. The derived nebular metallicities suggest either an external origin of the gas, or an overestimate of the oxygen yields by SN models. [ABRIDGED]

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SiO maser survey off the Galactic Plane: A signature of streaming motion

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A group of Mira variables in the solar neighborhood show unusual spatial motion in the Galaxy. To study this motion in a much larger scale in the Galaxy, we newly surveyed 134 evolved stars off the Galactic plane by SiO maser lines, obtaining accurate radial velocities of 84 detected stars. Together with the past data of SiO maser sources, we analyzed the radial velocity data of a large sample of sources distributing in a distance range of about 0.3–6 kpc in the first Galactic quadrant. At the Galactic longitudes between 20° and 40°, we found a group of stars with large negative radial velocities, which deviate by more than 100 km s^{-1} from the Galactic rotation. We show that these deviant motions of maser stars are created by periodic gravitational perturbation of the Bulge bar, and that the effect appears most strongly at radii between corotation and outer Lindblad resonances. The resonance effect can explain the displacement of positions from the Galactic Plane as well.

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Circumstellar molecular composition of the oxygen-rich AGB star IK Tau: I. Observations and LTE chemical abundance analysis

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Context. Molecular lines in the (sub)millimeter wavelength range can provide important information about the physical and chemical conditions in the circumstellar envelopes around asymptotic giant branch stars.
Aims. The aim of this paper is to study the molecular composition in the circumstellar envelope around the oxygen-rich star IK Tau.
Methods. We observed IK Tau in several (sub)millimeter bands using the APEX telescope during three observing periods. To determine the spatial distribution of the $^{12}CO(3 \rightarrow 2)$ emission, mapping observations were performed. To constrain the physical conditions in the circumstellar envelope, multiple rotational CO emission lines were modeled using a nonlocal thermodynamic equilibrium radiative transfer code. The rotational temperatures and the abundances of the other molecules were obtained assuming local thermodynamic equilibrium.
Results. An oxygen-rich asymptotic giant branch star has been surveyed in the submillimeter wavelength range.

Thirty four transitions of twelve molecular species, including maser lines, were detected. The kinetic temperature of the envelope was determined, and the molecular abundance fractions of the molecules were estimated. The deduced molecular abundances were compared with observations and modeling from the literature and agree within a factor of 10, except for SO_2, which is found to be almost a factor 100 stronger than predicted by chemical models. Conclusions. From this study, we found that IK Tau is a good laboratory for studying the conditions in circumstellar envelopes around oxygen-rich stars with (sub)millimeter-wavelength molecular lines.We could also expect from this study that the molecules in the circumstellar envelope can be explained more faithfully by non-LTE analysis with lower and higher transition lines than by simple LTE analysis with only lower transition lines. In particular, the observed CO line profiles could be well reproduced by a simple expanding envelope model with a power-law structure.

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The second and third parameters of the horizontal branch in globular clusters

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The second parameter (the first being metallicity) defining the distribution of stars on the horizontal branch (HB) of globular clusters (GCs) has long been one of the major open issues in our understanding of the evolution of normal stars. Large photometric and spectroscopic databases are now available: they include large and homogeneous sets of colour–magnitude diagrams, cluster ages, and homogeneous data about chemical compositions from our FLAMES survey. We use these databases to re-examine this issue. We use the photometric data to derive median and extreme (i.e., the values including 90% of the distribution) colours and magnitudes of stars along the HB for about a hundred GCs. We transform these into median and extreme masses of stars on the HB, using the models developed by the Pisa group, and taking into account evolutionary effects. We compare these masses with those expected at the tip of the red giant branch (RGB) to derive the total mass lost by the stars. We find that a simple linear dependence on metallicity of this total mass lost describes quite well the median colours of HB stars. Assuming this mass loss law to be universal, we find that age is the main second parameter, determining many of the most relevant features related to HBs. In particular, it allows us to explain the Oosterhoff dichotomy as a consequence of the peculiar age–metallicity distribution of GCs in our Galaxy, although both Oosterhoff groups have GCs spanning a rather large range in ages. However, at least an additional — third — parameter is clearly required. The most likely candidate is the He abundance, which might be different in GC stars belonging to the different stellar generations whose presence was previously derived from the Na–O and Mg–Al anticorrelations. Variations in the median He abundance allow us to explain the extremely blue HB of GCs like NGC 6254 (= M 10) and NGC 1904 (= M 79); such variations are found to be (weakly) correlated with the values of the R-parameter (that is the ratio of the number of stars on the HB and on the RGB). We also show that suitable He abundances allow deriving ages from the HB which are consistent with those obtained from the Main Sequence. Small corrections to these latter ages are then proposed. We find that a very tight age–metallicity relation (with a scatter below 4%) can be obtained for GCs kinematically related to the disk and bulge, once these corrections are applied. Furthermore, star-to-star variations in the He content, combined with a small random term, explain very well the extension of the HB. There is a strong correlation between this extension and the interquartile of the Na–O anticorrelation, strongly supporting the hypothesis that the third parameter for GC HBs is He. Finally, there are strong indications that the main driver for these variations in the He-content within GCs is the total cluster mass. There are a few GCs exhibiting exceptional behaviours (including NGC 104 = 47 Tuc and in less measure NGC 5272 = M 3); however, they can be perhaps accommodated in a scenario for the formation of GCs that relates their origin to cooling flows generated after very large episodes of star formation, as proposed by Carretta et al. (2009d).

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Herschel PACS and SPIRE imaging of CW Leo

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Herschel PACS and SPIRE images have been obtained over a $30' \times 30'$ area around the well-known carbon star CW Leo (IRC +10 216). An extended structure is found in an incomplete arc of $\sim 22'$ diameter, which is cospatial with the termination shock due to interaction with the interstellar medium (ISM) as defined by Sahai & Chronopoulos from ultraviolet GALEX images. Fluxes are derived in the 70, 160, 250, 350, and 550 μm bands in the region where the interaction with the ISM takes place, and this can be fitted with a modified black body with a temperature of 25 ± 3 K. Using the published proper motion and radial velocity for the star, we derive a heliocentric space motion of 25.1 km s^{-1}. Using the PACS and SPIRE data and the analytical formula of the bow shock structure, we infer a de-projected standoff distance of the bow shock of $R_0 = (8.0 \pm 0.3) \times 10^{17}$ cm. We also derive a relative velocity of the star with respect to the ISM of $(106.6 \pm 8.7)/\sqrt{n_{\rm ISM}}$ km s^{-1}, where $n_{\rm ISM}$ is the number density of the local ISM.

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Herschel images of NGC 6720: H_2 formation on dust grains

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Herschel PACS and SPIRE images have been obtained of NGC 6720 (the Ring Nebula). This is an evolved planetary nebula with a central star that is currently on the cooling track, due to which the outer parts of the nebula are recombining. From the PACS and SPIRE images we conclude that there is a striking resemblance between the dust distribution and the H_2 emission, which appears to be observational evidence that H_2 forms on grain surfaces. We have developed a photoionization model of the nebula with the Cloudy code which we used to determine the physical conditions of the dust and investigate possible formation scenarios for the H_2. We conclude that the most plausible scenario is that the H_2 resides in high density knots which were formed after the recombination of the gas started when the central star entered the cooling track. Hydrodynamical instabilities due to the unusually low temperature of the recombining gas are proposed as a mechanism for forming the knots. H_2 formation in the knots is expected to be substantial after the central star underwent a strong drop in luminosity about one to two thousand years ago, and may still be ongoing at this moment, depending on the density of the knots and the properties of the grains in the knots.

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Testing mass loss in Large Magellanic Cloud Cepheids using infrared and optical observations II. Predictions and tests of the OGLE-III fundamental-mode Cepheids

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In this article, we test the hypothesis that Cepheids have infrared excesses due to mass loss. We fit a model using the mass-loss rate and the stellar radius as free parameters to optical observations from the OGLE-III survey and infrared observations from the 2MASS and SAGE data sets. The sample of Cepheids have predicted minimum mass-loss rates ranging from zero to 10^{-8} $M_\odot$ yr^{-1}, where the rates depend on the chosen dust properties. We use the predicted radii to compute the Period–Radius relation for LMC Cepheids, and to estimate the uncertainty caused by the presence of infrared excess for determining angular diameters with the infrared surface brightness technique. Finally, we calculate the linear and non-linear Period–Luminosity (P–L) relations for the LMC Cepheids at $VIJHK$ + IRAC wavelengths and we find that the P–L relations are consistent with being non-linear at infrared wavelengths, contrary to previous results.

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An XMM-Newton view of Planetary Nebulae in the Small Magellanic Cloud. The X-ray luminous central star of SMP SMC 22

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During an X-ray survey of the Small Magellanic Cloud, carried out with the XMM-Newton satellite, we detected significant soft X-ray emission from the central star of the high-excitation planetary nebula SMP SMC 22. Its very soft spectrum is well fit with a non local thermodynamical equilibrium model atmosphere composed of H, He, C, N, and O, with abundances equal to those inferred from studies of its nebular lines. The derived effective temperature of 1.5×10^5 K is in good agreement with that found from the optical/UV data. The unabsorbed flux in the 0.1–0.5 keV range is $\sim 3 \times 10^{-11}$ erg cm^{-2} s^{-1}, corresponding to a luminosity of 1.2×10^{37} erg s^{-1} at the distance of 60 kpc. We also searched for X-ray emission from a large number of SMC planetary nebulae, confirming the previous detection of SMP SMC 25 with a luminosity of (0.2–6)$\times 10^{35}$ erg/s (0.1–1 keV). For the remaining objects that were not detected, we derived flux upper limits corresponding to luminosity values from several tens to hundreds times smaller than that of SMP SMC 22. The exceptionally high X-ray luminosity of SMP SMC 22 is probably due to the high mass of its central star, quickly evolving toward the white dwarf's cooling branch, and to a small intrinsic absorption in the nebula itself.

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Modification of nuclear transitions in stellar plasma by electronic processes: K-isomers in ^{176}Lu and ^{180}Ta under s-process conditions

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The influence of the stellar plasma on the production and destruction of K-isomers is studied for the examples ^{176}Lu and ^{180}Ta. Individual electromagnetic transitions are enhanced predominantly by nuclear excitation by electron capture, whereas the other mechanisms of electron scattering and nuclear excitation by electron transition give only minor contributions. It is found that individual transitions can be enhanced significantly for low transition energies below 100 keV. Transitions with higher energies above 200 keV are practically not affected. Although one low-energy transition in ^{180}Ta is enhanced by up to a factor of 10, the stellar transition rates from low-K to high-K states via so-called intermediate states in ^{176}Lu and ^{180}Ta do not change significantly under s-process conditions. The s-process nucleosynthesis of ^{176}Lu and ^{180}Ta remains essentially unchanged.

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Planetary nebulae abundances and stellar evolution II

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Context: In recent years mid- and far infrared spectra of planetary nebulae have been analysed and lead to more accurate abundances. It may be expected that these better abundances lead to a better understanding of the evolution of these objects. Aims: The observed abundances in planetary nebulae are compared to those predicted by the models of Karakas (2003) in order to predict the progenitor masses of the various PNe used. The morphology of the PNe is included in the comparison. Since the central stars play an important role in the evolution, it is expected that this comparison will yield additional information about them. Methods: First the nitrogen/oxygen ratio is discussed with relation to the helium/hydrogen ratio. The progenitor mass for each PNe can be found by a comparison with the models of Karakas. Then the present luminosity of the central stars is determined in two ways: first by computing the central star effective temperature and radius, and second by computing the nebular luminosity from the hydrogen and helium lines. This luminosity is also a function of the initial mass so that these two values of initial mass can be compared. Results: Six of the seven bipolar nebulae can be identified as descendants of high mass stars (4 $M_\odot$ – 6 $M_\odot$) while the seventh is ambiguous. Most of the elliptical PNe have central stars which descend from low initial mass stars, although there are a few caveats which are discussed. There is no observational evidence for a higher mass for central stars which have a high carbon/oxygen ratio. The evidence provided by the abundance comparison with the models of Karakas is consistent with the HR diagram to which it is compared. In the course of this discussion it is shown how 'optically thin' nebulae can be separated from those which are 'optically thick'.

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Rayleigh–Taylor finger instability mixing in hydrodynamic shell convection models

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Mixing processes in stars driven by composition gradients as a result of the Rayleigh–Taylor instability are not anticipated. They are supported only by hydrodynamic studies of stellar convection. We find that such mixing occurs below the bottom edge of convection zones in our multidimensional hydrodynamic shell convection models. It operates at interfaces created by off-center nuclear burning, where less dense gas with higher mean molecular weight is located above denser gas with a lower mean molecular weight. We discuss the mixing under various conditions with hydrodynamic convection models based on stellar evolutionary calculations of the core helium flash in a 1.25 $M_\odot$ star, the core carbon flash in a 9.3 $M_\odot$ star, and of oxygen burning shell in a star with a mass of 23 $M_\odot$. We simulate the hydrodynamic behavior of shell convection during various phases of stellar evolution with the Eulerian hydrodynamics code HERAKLES in two and three spatial dimensions. Initial models for this purpose are obtained by state-of-the-art stellar evolutionary codes, namely GARSTEC, STAREVOL, and TYCHO for the core helium flash, core carbon flash, and oxygen shell burning, respectively. Most of our analysis is performed for two-dimensional hydrodynamic models of shell convection during the core helium flash at its peak covering approximately 250 convective turnover timescales. The mixing manifests itself in the form of overdense and cold fingers enriched with matter of higher mean molecular weight, originating from density fluctuations at the lower boundary of the convective shell, and "shooting" down into the core. They result from the Rayleigh–Taylor instability at the lower convection zone boundary due to a negative mean molecular weight gradient. They do not appear when the mean molecular weight gradient is positive.

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The detached dust shells of AQ And, U Ant, and TT Cyg

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Detached circumstellar dust shells are detected around three carbon variables using *Herschel*-PACS. Two of them are already known on the basis of their thermal CO emission and two are visible as extensions in IRAS imaging data. By model fits to the new data sets, physical sizes, expansion timescales, dust temperatures, and more are deduced. A comparison with existing molecular CO material shows a high degree of correlation for TT Cyg and U Ant but a few distinct differences with other observables are also found.

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Rusty old stars: a source of the missing interstellar iron?

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Iron, the Universe's most abundant refractory element, is highly depleted in both circumstellar and interstellar environments, meaning it exists in solid form. The nature of this solid is unknown. In this Letter, we provide evidence that metallic iron grains are present around oxygen-rich AGB stars, where it is observationally manifest as a featureless mid-infrared excess. This identification is made using *Spitzer Space Telescope* observations of evolved globular cluster stars, where iron dust production appears ubiquitous and in some cases can be modelled as the only observed dust product. In this context, FeO is examined as the likely carrier for the 20-μm feature observed in some of these stars. Metallic iron appears to be an important part of the dust condensation sequence at low metallicity, and subsequently plays an influential role in the interstellar medium. We explore the stellar metallicities and luminosities at which iron formation is observed, and how the presence of iron affects the outflow and its chemistry. The conditions under which iron can provide sufficient opacity to drive a wind remain unclear.

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Stellar adiabatic mass-loss model and applications

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Roche-lobe overflow and common envelope evolution are very important in binary evolution, which is believed to be the main evolutionary channel to hot subdwarf stars. The details of these processes are difficult to model, but adiabatic expansion provides an excellent approximation to the structure of a donor star undergoing dynamical timescale mass transfer. We can use this model to study the responses of stars of various masses and evolutionary stages as potential donor stars, with the urgent goal of obtaining more accurate stability criteria for dynamical mass transfer in binary population synthesis studies. As examples, we describe here several models with the initial masses equal to 1 $M_\odot$ and 10 $M_\odot$, and identify potential limitations to the use of our results for giant branch stars.

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Who pulled the trigger: a supernova or an AGB star?

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The short-lived radioisotope ^{60}Fe requires production in a core collapse supernova or AGB star immediately before its incorporation into the earliest solar system solids. Shock waves from a somewhat distant supernova, or a relatively nearby AGB star, have the right speeds to simultaneously trigger the collapse of a dense molecular cloud core and to inject shock wave material into the resulting protostar. A new set of FLASH2.5 adaptive mesh refinement hydrodynamical models shows that the injection efficiency depends sensitively on the assumed shock thickness and density. Supernova shock waves appear to be thin enough to inject the amount of shock wave material necessary to match the short-lived radioisotope abundances measured for primitive meteorites. Planetary nebula shock waves from AGB stars, however, appear to be too thick to achieve the required injection efficiencies. These models imply that a supernova pulled the trigger that led to the formation of our solar system.

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A detailed look at chemical abundances in Magellanic Cloud planetary nebulae. I. The Small Magellanic Cloud

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We present an analysis of elemental abundances of He, N, O, Ne, S, and Ar in Magellanic Cloud planetary nebulae (PNe), and focus initially on 14 PNe in the Small Magellanic Cloud (SMC). We derived the abundances from a combination of deep, high dispersion optical spectra, as well as mid-infrared (IR) spectra from the Spitzer Space Telescope. A detailed comparison with prior SMC PN studies shows that significant variations among authors of relative emission line flux determinations lead to systematic discrepancies in derived elemental abundances between studies that are $\gtrsim$0.15 dex, in spite of similar analysis methods. We used ionic abundances derived from IR emission lines, including those from ionization stages not observable in the optical, to examine the accuracy of some commonly used recipes for ionization correction factors (ICFs). These ICFs, which were developed for ions observed in the optical and ultraviolet, relate ionic abundances to total elemental abundances. We find that most of these ICFs work very well even in the limit of substantially sub-Solar metallicities, except for PNe with very high ionization. Our abundance analysis shows enhancements of He and N that are predicted from prior dredge-up processes of the progenitors on the AGB, as well as the well known correlations among O, Ne, S, and Ar that are little affected by nucleosynthesis in this mass range. We identified MG 8 as an interesting limiting case of a PN central star with a $\sim 3.5\ M_\odot$ progenitor in which hot-bottom burning did not occur in its prior AGB evolution. We find no evidence for O depletion in the progenitor AGB stars via the O–N cycle, which is consistent with predictions for lower-mass stars. We also find low S/O ratios relative to SMC H II regions, with a deficit comparable to what has been found for Galactic PNe. Finally, the elemental abundances of one object, SMP-SMC 11, are more typical of SMC H II regions, which raises some doubt about its classification as a PN.

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Herschel-SPIRE FTS spectroscopy of the carbon-rich objects AFGL 2688, AFGL 618 and NGC 7027

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We present far-infrared and submillimetre spectra of three carbon-rich evolved objects, AFGL 2688, AFGL 618 and NGC 7027. The spectra were obtained with the SPIRE Fourier transform spectrometer on board the *Herschel* Space Observatory, and cover wavelengths from 195–670 μm, a region of the electromagnetic spectrum hitherto difficult to study in detail. The far infrared spectra of these objects are rich and complex, and we measure over 150 lines in each object. Lines due to 18 different species are detected. We determine physical conditions from observations of the rotational lines of several molecules, and present initial large velocity gradient models for AFGL 618. We detect water in AFGL 2688 for the first time, and confirm its presence in AFGL 618 in both ortho and para forms. In addition, we report the detection of the $J = 1 - 0$ line of CH^+ in NGC 7027.

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PACS and SPIRE spectroscopy of the red supergiant VY CMa

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With a luminosity $> 10^5$ $L_\odot$ and a mass-loss rate of about 2×10^{-4} $M_\odot$ yr^{-1}, the red supergiant VY CMa truly is a spectacular object. Because of its extreme evolutionary state, it could explode as supernova any time. Studying its circumstellar material, into which the supernova blast will run, provides interesting constraints on supernova explosions and on the rich chemistry taking place in such complex circumstellar envelopes. We have obtained spectroscopy of VY CMa over the full wavelength range offered by the PACS and SPIRE instruments of Herschel, i.e. 55 to 672 μm. The observations show the spectral fingerprints of more than 900 spectral lines, of which more than half belong to water. In total, we have identified 13 different molecules and some of their isotopologues. A first analysis shows that water is abundantly present, with an ortho-to-para ratio as low as 1.3:1, and that chemical non-equilibrium processes determine the abundance fractions in the inner envelope.

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Silicon in the dust formation zone of IRC +10 216 as seen by PACS and SPIRE on board Herschel

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The interstellar medium is enriched primarily by matter ejected from evolved low and intermediate mass stars. The outflows from these stars create a circumstellar envelope in which a rich gas-phase and dust-nucleation chemistry takes place. We observed the nearest carbon-rich evolved star, IRC +10 216, using the PACS (55–210 μm) and SPIRE (194–672 μm) spectrometers on board Herschel. We find several tens of lines from SiS and SiO, including lines from the $v = 1$ vibrational level. For SiS these transitions range up to $J = 124 \rightarrow 123$, corresponding to energies around 6700 K, while the highest detectable transition is $J = 90 \rightarrow 89$ for SiO, which corresponds to an energy around 8400 K. Both species trace the dust formation zone of IRC +10 216, and the broad energy ranges involved in their detected transitions permit us to derive the physical properties of the gas and the particular zone in which each species has been formed. This allows us to check the accuracy of chemical thermodynamical equilibrium models and the suggested depletion of SiS and SiO due to accretion onto dust grains.

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Circumstellar molecular composition of the oxygen-rich AGB star IK Tau: II. In-depth non-LTE chemical abundance analysis

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Context: The interstellar medium is enriched primarily by matter ejected from evolved low and intermediate mass stars. The outflow from these stars creates a circumstellar envelope in which a rich gas-phase chemistry takes place. Complex shock-induced nonequilibrium chemistry takes place in the inner wind envelope, dust-gas reactions and ion-molecule reactions alter the abundances in the intermediate wind zone, and the penetration of cosmic rays and ultraviolet photons dissociates the molecules in the outer wind region.
Aims: Little observational information exists on the circumstellar molecular abundance stratifications of many molecules. Furthermore, our knowledge of oxygen-rich envelopes is not as profound as for the carbon-rich counterparts. The aim of this paper is therefore to study the circumstellar chemical abundance pattern of 11 molecules and isotopologs (^{12}CO, ^{13}CO, SiS, ^{28}SiO, ^{29}SiO, ^{30}SiO, HCN, CN, CS, SO, SO_2) in the oxygen-rich evolved star IK Tau.
Methods: We have performed an in-depth analysis of a large number of molecular emission lines excited in the circumstellar envelope around IK Tau. The analysis is done based on a non-local thermodynamic equilibrium (non-LTE)

radiative transfer analysis, which calculates the temperature and velocity structure in a self-consistent way. The chemical abundance pattern is coupled to theoretical outer wind model predictions including photodestruction and cosmic ray ionization. Not only the integrated line intensities, but also the line shapes are used as diagnostic tool to study the envelope structure.
Results: The deduced wind acceleration is much slower than predicted from classical theories. SiO and SiS are depleted in the envelope, possibly due to the adsorption onto dust grains. For HCN and CS a clear difference with respect to inner wind non-equilibrium predictions is found, either indicating uncertainties in the inner wind theoretical modeling or the possibility that HCN and CS (or the radical CN) participate in the dust formation. The low signal-to-noise profiles of SO and CN prohibit an accurate abundance determination; the modeling of high-excitation SO_2 lines is cumbersome, possibly related to line misidentifications or problems with the collisional rates. The SiO isotopic ratios (^{29}SiO/^{28}SiO and ^{30}SiO/^{28}SiO) point toward an enhancement in ^{28}SiO compared to results of classical stellar evolution codes. Predictions for H_2O emission lines in the spectral range of the Herschel/HIFI mission are performed.

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Substellar companions to evolved intermediate-mass stars: HD 145457 and HD 180314

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We report the detections of two substellar companions orbiting around evolved intermediate-mass stars from precise Doppler measurements at Subaru Telescope and Okayama Astrophysical Observatory. HD 145457 is a K0 giant with a mass of 1.9 $M_\odot$ and has a planet of minimum mass $m_2 \sin i = 2.9$ M_J orbiting with period of $P = 176$ d and eccentricity of $e = 0.11$. HD 180314 is also a K0 giant with 2.6 $M_\odot$ and hosts a substellar companion of $m_2 \sin i = 22 M_J$, which falls in brown-dwarf mass regime, in an orbit with $P = 396$ d and $e = 0.26$. HD 145457 b is one of the innermost planets and HD 180314 b is the seventh candidate of brown-dwarf-mass companion found around intermediate-mass evolved stars.

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The peculiar dust shell of Nova DZ Cru (2003)

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We present *Spitzer Space Telescope* observations of the "peculiar variable" DZ Cru, identified by Rushton et al. (2008, MNRAS, 386, 289) as a classical nova. A dust shell, on which are superimposed a number of features, is prominent in the 5–35 μm range some 4 years after eruption. We suggest that the dust in DZ Cru is primarily hydrogenated amorphous carbon in which aliphatic bands currently predominate, and which may either become predominantly aromatic as the dust is photo-processed by ultraviolet radiation from the stellar remnant, or more likely completely destroyed.

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Low-temperature crystallization of amorphous silicate in astrophysical environments

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We construct a theoretical model for low-temperature crystallization of amorphous silicate grains induced by exothermic chemical reactions. As a first step, the model is applied to the annealing experiments, in which the samples are (1) amorphous silicate grains and (2) amorphous silicate grains covered with an amorphous carbon layer. We derive the activation energies of crystallization for amorphous silicate and amorphous carbon from the analysis of the experiments. Furthermore, we apply the model to the experiment of low-temperature crystallization of amorphous silicate core covered with an amorphous carbon layer containing reactive molecules. We clarify the conditions of low-temperature crystallization due to exothermic chemical reactions. Next, we formulate the crystallization conditions so as to be applicable to astrophysical environments. We show that the present crystallization mechanism is characterized by two quantities: the stored energy density Q in a grain and the duration of the chemical reactions τ. The crystallization conditions are given by $Q > Q_{\min}$ and $\tau < \tau_{\rm cool}$ regardless of details of the reactions and grain structure, where $\tau_{\rm cool}$ is the cooling timescale of the grains heated by exothermic reactions, and $Q_{\min}$ is minimum stored energy density determined by the activation energy of crystallization. Our results suggest that silicate crystallization occurs in wider astrophysical conditions than hitherto considered.

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On the need for deep-mixing in Asymptotic Giant Branch stars of low mass

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The photospheres of low-mass red giants show CNO isotopic abundances that are not satisfactorily accounted for by canonical stellar models. The same is true for the measurements of these isotopes and of the ^{26}Al/^{27}Al ratio in presolar grains of the circumstellar origin. Non-convective mixing, occurring during both red giant branch (RGB) and asymptotic giant branch (AGB) stages, is the explanation commonly invoked to account for the above evidence. Recently, the need for such mixing phenomena on the AGB was questioned, and chemical anomalies usually attributed to them were suggested to be formed in earlier phases. We have therefore re-calculated extra-mixing effects in low-mass stars for both the RGB and AGB stages, in order to verify the above claims. Our results contradict them; we actually confirm that slow transport below the convective envelope occurs also on the AGB. This is required primarily by the oxygen isotopic mix and the ^{26}Al content of presolar oxide grains. Other pieces of evidence exist, in particular from the isotopic ratios of carbon stars of type N, or C(N), in the Galaxy and in the LMC, as well as of SiC grains of the AGB origin. We further show that, when extra-mixing occurs in the RGB phases of population I stars above about 1.2 $M_\odot$, this consumes ^{3}He in the envelope, probably preventing the occurrence of thermohaline diffusion on the AGB. Therefore, we argue that other extra-mixing mechanisms should be active in those final evolutionary phases.

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Dust is forming along the Red Giant Branch of 47 Tuc

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We present additional evidence that dust is really forming along the red giant branch (RGB) of 47 Tuc at luminosities ranging from above the horizontal branch to the RGB-tip (Origlia et al. 2007). The presence of dust had been inferred from an infrared excess in the (K–8) color, with K measured from high spatial resolution ground based near-IR photometry and "8" referring to Spitzer-IRAC 8 μm photometry. We show how (K–8) is a far more sensitive diagnostic for detecting tiny circumstellar envelopes around warm giants than colors using only the Spitzer-IRAC bands, for example the (3.6–8) color used by Boyer et al. (2010). In addition, we also show high resolution HST-ACS I band images of the giant stars which have (K–8) color excess. These images clearly demonstrate that Boyer et al. (2010) statement that our detections of color excess associated with stars below the RGB-tip arise from blends and artefacts is simply not valid.

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Conference Papers

The case of the disappearing CN-strong AGB stars in Galactic globular clusters — Preliminary results

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A previously reported literature search suggested that the AGB stars in Galactic globular clusters may be showing different distributions of CN-strong and CN-weak stars as compared to their RGB stars. In most cases the second giant branches of GCs appeared to be deficient in stars with strong CN bands. However the sample sizes of AGB stars at that time were too small to give a definitive picture. Thus an observing campaign targeting GC AGB stars was proposed. We now have medium resolution spectral observations of about 250 GC AGB stars across 9 globular clusters, obtained with the 2dF/AAOmega instrument on the Anglo-Australian Telescope. In this paper we report some preliminary results regarding the distributions of CN-strong and CN-weak stars on the two giant branches of a selection of globular clusters. We find that some GCs show a total lack of CN-strong stars on the AGB, whilst some show a reduction in CN-strong stars as compared to the RGB. Standard stellar evolution does not predict this change in surface abundance between the two giant branches. We discuss some possible causes of this unexpected phenomenon.

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Some caveats about the evolution of the N/O abundance and the star formation history.

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We carefully analyze how the abundance of Nitrogen over Oxygen evolves when dependent on metallicity stellar yields with a primary component of N proceeding from AGBs stars are used. We show the results obtained with a chemical evolution models grid, calculated with variable star formation efficiencies, which produce different star formation histories. Finally we see how the N/O abundance is related on the evolutionary history.

Oral contribution, published in 10$^{\text{th}}$ Torino workshop on AGB nucleosynthesis
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The composition of RR Lyrae stars: Start-line for the AGB

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This paper sumarizes research on abundances in RR Lyrae stars that one of us (GW) has been engaged in with various astronomers. In addition we report on preliminary analysis of the abundances of C, Si, S and Fe in 24 RR Lyrae stars. Our model atmosphere analysis, including NLTE effects, are based on the spectra of resolving power 30,000 obtained

at the Apache Poing Observatory.

Oral contribution, published in The 10^{th} **Torino Workshop on Asymptotic Giant Branch Nucleosynthesis**
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High resolution spectroscopy of the planetary nebulae PM 1-242, PM 1-318 and PM 1-322

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We have recently confirmed the planetary nebula (PN) nature of PM 1-242, PM 1-318 and PM 1-322. Here we present high-resolution long-slit spectra of these three PNe in order to analyze their internal kinematics and to investigate their physical structure. PM 1-242 is a tilted ring and not an elliptical PN as suggested by direct images. The object is probably related to ring-like PNe and shows an unusual point-symmetric brightness distribution in the ring. PM 1-318 is a pole-on elliptical PN, instead of a circular one as suggested by direct images. PM 1-322 is spatially unresolved and its spectrum shows large differences between the forbidden lines and Hα profiles, with the latter showing a double-peaked profile and relatively extended wings (FWZI $\sim$ 325 km s^{-1}). These properties are found in other PNe that are suspected to host a symbiotic central star.

Poster contribution, published in "Legacies of the Macquarie/AAO/Strasbourg Hα Planetary Nebula Project", PASA (refereed)
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Review Paper

Chromospheres and winds of red supergiants: An empirical look at outer atmospheric structure

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Stars between about 4 and 25 M$_\odot$ spend a significant fraction of their post-main sequence lifetime as red supergiants (RSGs) and lose material via stellar winds during this period. For RSGs more massive than 10 M$_\odot$, this mass loss becomes of evolutionary significance, and probably determines the upper mass limit of RSGs in the Hertzsprung–Russell diagram. Despite decades of observations, the driving mechanism responsible for mass loss in RSGs remains unknown. Mainly this is because the optical spectrum accessible from the ground provides almost no useful wind diagnostics, and what information is obtained is spatially averaged over the entire wind volume. However, within the last decade, *Hubble Space Telescope (HST)* observations of many useful ultraviolet wind diagnostics have been obtained at a high signal-to-noise ratio and spectral resolution. In particular, RSGs in eclipsing binaries can provide spatially resolved observations of stellar chromospheres and winds. I review possible RSG wind acceleration mechanisms, discuss some observational constraints, and present some empirical models of RSG chromospheres and winds.

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