THE AGB NEWSLETTER

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Editorial

Dear Colleagues,

It is a pleasure to present you the 278th issue of the AGB Newsletter. People (and editors) are catching up, resulting in a resurgence of activity posted in this edition. Look for the slightly unusual ones, such as the use of medical diagnosis and how grains form under different conditions. There is great scope for the application of techniques and insight from other disciplines, and vice versa. Betelgeuse also continues to capture the imagination (and observation), and there are two very interesting reviews related to the fundamental properties of red giant stars. And lots more.

The IAU Working Group on Planetary Nebulæ is reaching out to the community to help build a repository of learning material for novices in the field – a great idea that we strongly endorse and would encourage you to consider.

Elizabeth Griffin responded to last month's *Food for Thought* ("How well do we know how the Sun will evolve into an AGB star?"):

"First, science isn't about *know*ing, it's about approximating to what can be regarded as *know*ledge through repeated trials and tests, the state when hypotheses might be regarded as 'theories'. The example above is particularly trying since we cannot carry out control experiments. It is largely about likelihoods, which are based on statistics and only apply to a general mean, so they are inherently false when applied to any one individual case.
Secondly, every star is an individual when observed in sufficient detail (did we ever conclusively find 'The Solar Twin'?). The effective temperature of the Sun is no measured temperature, as is so often assumed, but a parameter that represents the smoothed spectral energy distribution according to a particular law, again an assumption that the said law applies. Is 'An AGB Star' anything other than a description of a rather vague state whose bounds are broad enough to admit pseudo-AGB types that are not fully commensurate with the general situation, rather than a state which can be said to be reached very definitively at a very specific combination of a star's luminosity and surface (or effective? or excitation?, or ionization?) temperature?
Thirdly, how likely is it that the Sun will obediently obey your stellar-evolution codes (that may or may not make allowances for observations that smooth over surface granulation and the like, and which assumes no absorption in the chromosphere which we know is present, and is variable), and conform to a pattern that only much less well observed stars seem to do, and not prove to be some exception that tests all those hypotheses? You could save time by getting out your crystal ball."

Further discussion is encouraged – it is not irrelevant that astronomers know the ultimate fate (and timescales) of "our" star, and hence the Earth. We know the Sun formed 4.6 Gyr ago, but we cannot tell with such confidence when it will end. Will there be a safe place for us to live in the Solar System?

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

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

Food for Thought

This month's thought-provoking statement is:

What is Betelgeuse going to do next?

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

Refereed Journal Papers

The post-common-envelope binary central star of the planetary nebula PN G283.7−05.1: A possible post-red-giant-branch planetary nebula central star

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We present the discovery and characterisation of the post-common-envelope central star system in the planetary nebula PN G283.7−05.1. Deep images taken as part of the POPIPlaN survey indicate that the nebula may possess a bipolar morphology similar to other post-common-envelope planetary nebulæ. Simultaneous light and radial velocity curve modelling reveals the newly discovered binary system to comprise a highly-irradiated, M-type main-sequence star in a 5.9 hour orbit with a hot pre-white-dwarf. The nebular progenitor is found to have a particularly low mass of around 0.4 $M_\odot$, making PN G283.7−05.1 one of only a handful of candidate planetary nebulæ to be the product of a common-envelope event while still on the red giant branch. Beyond its low mass, the model temperature, surface gravity and luminosity are all found to be consistent with the observed stellar and nebular spectra through comparison with model atmospheres and photoionisation modelling. However, the high temperature ($T_{\rm eff} \sim 95$ kK) and high luminosity of the central star of the nebula are not consistent with post-RGB evolutionary tracks.

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Abell 30 – a binary central star among the born-again planetary nebulæ

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Eight planetary nebulæ have been identified as 'born-again', a class of object typified by knotty secondary ejecta having low masses ($\sim 10^{-4}$ $M_\odot$) with nearly no hydrogen. Abell 30, the archetype of the class, also belongs to a small subset of planetary nebulae that exhibit extreme abundance discrepancy factors (where Abell 30 is the most extreme), a phenomenon strongly linked to binary star interactions. We report the presence of light curve brightness variations having a period of 1.060 days that are highly suggestive of a binary central star in Abell 30. If confirmed, this detection supports the proposed link between binary central stars and extreme abundance discrepancies.

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Available from https://arxiv.org/abs/2008.01488

Adiabatic mass loss in binary stars – III. From the base of the red giant branch to the tip of the asymptotic giant branch

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The distinguishing feature of the evolution of close binary stars is the role played by the mass exchange between the component stars. Whether the mass transfer is dynamically stable is one of the essential questions in binary evolution. In the limit of extremely rapid mass transfer, the response of a donor star in an interacting binary becomes asymptotically one of adiabatic expansion. We use the adiabatic mass loss model to systematically survey the thresholds for dynamical timescale mass transfer over the entire span of possible donor star evolutionary states. We also simulate mass loss process with isentropic envelopes, the specific entropy of which is fixed to be that at the base of the convective envelope, to artificially mimic the effect of such mass loss in super-adiabatic surface convection regions, where the adiabatic approximation fails. We illustrate the general adiabatic response of 3.2-$M_\odot$ donor stars at different evolutionary stages. We extend our study to a grid of donor stars with different masses (from 0.1 to 100 $M_\odot$ with $Z = 0.02$) and at different evolutionary stages. We proceed to present our criteria for dynamically unstable mass transfer in both tabular and graphical forms. For red giant branch and asymptotic giant branch donors in systems with such mass ratios, they may have convective envelopes deep enough to evolve into common envelopes on a thermal timescale, if the donor star overfills its outer Lagrangian radius. Our results show that the red giant branch and asymptotic giant branch stars tend to be more stable than previously believed, and this may be helpful to explain the abundance of observed post-AGB binary stars with an orbital period of around 1000 days.

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Bi-abundance photoionization models of planetary nebulæ: determining the amount of oxygen in the metal rich component

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We study the hypothesis of high metallicity clumps being responsible for the abundance discrepancy found in planetary nebulæ between the values obtained from recombination and collisionally excited lines. We generate grids of photoionization models combining cold metal-rich clumps emitting the heavy element recombination lines, embedded in a normal metallicity region responsible for the forbidden lines. The two running parameters of the grid are the metallicity of the clumps and its volume fraction relative to the whole nebula. We determine the density and temperatures (from the Balmer jump and the [O III] 5007/4363 Å line ratio), and the ionic abundances from the collisional and recombination lines, as an observer would do. The metallicity of the near-to-solar region is recovered, while the metallicity of the clumps is systematically underestimated, by up to 2 orders of magnitude. This is mainly because most of the Hβ emission is coming from the "normal" region, and only the small contribution emitted by the metal-rich clumps should be used. We find that a given ADF(O^{++}) can be reproduced by a small amount of rich clumps, or a bigger amount of less rich clumps. Finally, comparing with the observations of NGC 6153 we find 2 models that reproduce its ADF(O^{++}) and the observed electron temperatures. We determine the fraction of oxygen embedded in the metal-rich region (with a fraction of volume less than 1%) to be roughly between 25% and 60% of the total amount of oxygen in the nebula (a few 10^{-3} $M_\odot$).

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The impact of strong recombination on temperature determination in planetary nebulæ

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The long-standing difference in chemical abundances determined from optical recombination lines and collisionally excited lines raises questions about our understanding of atomic physics, as well as the assumptions made when determining physical conditions and chemical abundances in astrophysical nebulæ. Here, we study the recombination contribution of [O III] 4363 and the validity of the line ratio [O III] 4363/4959 as a temperature diagnostic in planetary nebulæ with a high abundance discrepancy. We derive a fit for the recombination coefficient of [O III] 4363 that takes into account the radiative and dielectronic recombinations, for electron temperatures from 200 to 30,000 K. We estimate the recombination contribution of [O III] 4363 for the planetary nebulæ Abell 46 and NGC 6778 by subtracting the collisional contribution from the total observed flux. We find that the spatial distribution for the estimated recombination contribution in [O III] 4363 follows that of the O II 4649 recombination line, both peaking in the central regions of the nebula, especially in the case of Abell 46 which has a much higher abundance discrepancy. The estimated recombination contribution reaches up to 70% and 40% of the total [O III] 4363 observed flux, for Abell 46 and NGC 6778, respectively.

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The halo of M 105 and its group environment as traced by planetary nebula populations – I. Wide-field photometric survey of planetary nebulæ in the Leo I group

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M 105 (NGC 3379) is an early-type galaxy in the Leo I group. The Leo I group is the nearest group that contains all main galaxy types and can thus be used as a benchmark to study the properties of the intra-group light (IGL) in low-mass groups. We present a photometric survey of planetary nebulæ (PNe) in the extended halo of the galaxy to characterise its PN populations and investigate the presence of an extended PN population associated with the intra-group light. We use PNe as discrete stellar tracers of the diffuse light around M 105. These PNe were identified on the basis of their bright [O III]5007Å emission and the absence of a broad-band continuum using automated detection techniques. We compare the PN number density profile with the galaxy surface-brightness profile decomposed into metallicity components using published photometry of the *Hubble* Space Telescope in two halo fields. We identify 226 PNe candidates within a limiting magnitude of $m_{5007,\mathrm{lim}} = 28.1$ from our Subaru-SuprimeCam imaging, covering 67.6

kpc (23 effective radii) along the major axis of M 105 and the halos of NGC 3384 and NGC 3398. We find an excess of PNe at large radii compared to the stellar surface brightness profile from broad-band surveys. This excess is related to a variation in the luminosity-specific PN number α with radius. The α-parameter value of the extended halo is more than seven times higher than that of the inner halo. We also measure an increase in the slope of the PN luminosity function at fainter magnitudes with radius. We infer that the radial variation of the PN population properties is due to a diffuse population of metal-poor stars ([M/H] < -1.0) following an exponential profile, in addition to the M 105 halo. The spatial coincidence between the number density profile of these metal-poor stars and the increase in the α-parameter value with radius establishes the missing link between metallicity and the post-asymptotic giant branch phases of stellar evolution. We estimate that the total bolometric luminosity associated with the exponential IGL population is 2.04×10^9 $L_\odot$ as a lower limit. The lower limit on the IGL fraction is thus 3.8%. This work sets the stage for kinematic studies of the IGL in low-mass groups.

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V725 Sagittarii: unique, important, neglected

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During the last century, V725 Sgr gradually changed from a 12-day Cepheid to an 85-day yellow semiregular giant. This paper presents wavelet analysis of AAVSO visual observations from 1982 to 2020, and Fourier analysis of ASAS-SN observations from 2016 to 2018. The results confirm that the previously identified pulsation period has increased from about 50–60 days to 80–90 days since 1982. In the ASAS-SN data, there appear to be both an 82.6-day period and a possible 160.0-day period, though the latter is not prominent after pre-whitening. If it is real, however, the two periods could be interpreted as a first overtone period and a fundamental period, respectively. Evidence for two (or more) periods can also be seen in the ASAS-SN light curve, and in the visual data. The total V range is 1.1 magnitude. Since recent results in the literature indicate that V725 Sgr is a K4 yellow giant, it should be classified as a SRd variable. In view of its continuing changes, it needs and deserves to be monitored more systematically.

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Analysis of ASAS-SN observations of short-period Mira stars

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We have analyzed observations of a uniform sample of 36 stars in the ASAS-SN variable star catalogue, with mean magnitudes between 10 and 12, classified as Mira by the catalogue, and with periods of 150 days or less. They presumably represent a transition from Mira type to semiregular type. The stars show a wide variety of light curve shapes, and of deviation from periodicity. The amplitude increases with increasing period, as is well known, but no other properties, including the degree of periodicity, seem to depend on period.

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A detailed view on the circumstellar environment of the M-type AGB star EP Aquarii – I. High-resolution ALMA and SPHERE observations

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Cool evolved stars are known to be significant contributors to the enrichment of the interstellar medium through their dense and dusty stellar winds. High resolution observations of these outflows have shown them to possess high degrees of morphological complexity. We observed the asymptotic giant branch (AGB) star EP Aquarii with ALMA in band 6 and VLT/SPHERE/ZIMPOL in four filters the visible. Both instruments had an angular resolution of $0\farcs025$. These are follow-up observations to the lower-resolution 2016 ALMA analysis of EP Aquarii, which revealed that its wind possesses a nearly face-on, spiral-harbouring equatorial density enhancement, with a nearly pole-on bi-conical outflow. At the base of the spiral, the SiO emission revealed a distinct emission void approximately $0\farcs4$ to the West of the continuum brightness peak, which was proposed to be linked to the presence of a companion. The new ALMA data better resolve the inner wind and reveal that its morphology as observed in CO is consistent with hydrodynamical companion-induced perturbations. Assuming that photodissociation by the UV-field of the companion is responsible for the emission void in SiO, we deduced the spectral properties of the tentative companion from the size of the hole. We conclude that the most probable companion candidate is a white dwarf with a mass between 0.65 and 0.8 $M_\odot$, though a solar-like companion could not be definitively excluded. The radial SiO emission shows periodic, low-amplitude perturbations. We tentatively propose that they could be the consequence of the interaction of the AGB wind with another much closer low-mass companion. The polarised SPHERE/ZIMPOL data show a circular signal surrounding the AGB star with a radius of $\sim 0\farcs1$. Decreased signal along a PA of 138° suggests that the dust is confined to an inclined ring-like structure, consistent with the previously determined wind morphology.

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PHAT XX. AGB stars and other cool giants in M 31 star clusters

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The presence of AGB stars in clusters provides key constraints for stellar models, as has been demonstrated with historical data from the Magellanic Clouds. In this work, we look for candidate AGB stars in M 31 star clusters from the Panchromatic *Hubble* Andromeda Treasury (PHAT) survey. Our photometric criteria selects stars brighter than the tip of the red giant branch, which includes the bulk of the thermally-pulsing AGB stars as well as early-AGB stars and other luminous cool giants expected in young stellar populations (e.g., massive red supergiants, and intermediate-mass red helium-burning stars). The AGB stars can be differentiated, a posteriori, using the ages already estimated for our cluster sample. 937 candidates are found within the cluster aperture radii, half (450) of which are very likely cluster members. Cross-matching with additional databases reveals two carbon stars and ten secure variables among them. The field-corrected age distribution reveals the presence of young supergiants peaking at ages smaller than 100 Myr, followed by a long tail of AGB stars extending up to the oldest possible ages. This long tail reveals the general decrease in the numbers of AGB stars from initial values of $50\times10^{-6}/\mathrm{M}_\odot$ at 100 Myr down to $5\times10^{-6}/\mathrm{M}_\odot$ at 10 Gyr. Theoretical models of near-solar metallicity reproduce this general trend, although with localized discrepancies over some age intervals, whose origin is not yet identified. The entire catalogue is released together with finding charts to facilitate follow-up studies.

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Progenitor, precursor and evolution of the dusty remnant of the stellar merger M31-LRN-2015

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M31-LRN-2015 is a likely stellar merger discovered in the Andromeda Galaxy in 2015. We present new optical to mid-infrared photometry and optical spectroscopy for this event. Archival data shows that the source started to brighten $\sim$ 2 years before the nova event. During this precursor phase, the source brightened by $\sim$ 3 mag. The lightcurve at 6 and 1.5 months before the main outburst may show periodicity, with periods of 16 ± 0.3 and 28.1 ± 1.4 days respectively. This complex emission may be explained by runaway mass loss from the system after the binary undergoes Roche-lobe overflow, leading the system to coalesce in tens of orbital periods. While the progenitor spectral energy distribution shows no evidence of pre-existing warm dust in system, the remnant forms an optically thick dust shell at $\sim$ 4 months after the outburst peak. The optical depth of the shell increases dramatically after 1.5 years, suggesting the existence of shocks that enhance the dust formation process. We propose that the merger remnant is likely an inflated giant obscured by a cooling shell of gas with mass ~ 0.2 M$_\odot$ ejected at the onset of the common envelope phase.

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Evidence for localized onset of episodic mass loss in Mira

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Context: Mass loss from long-period variable stars (LPV) is an important contributor to the evolution of galactic

abundances. Dust formation is understood to play an essential role in mass loss. It has, however, proven difficult to develop measurements that strongly constrain the location and timing of dust nucleation and acceleration.
Aims: Interferometric imaging has the potential to constrain the geometry and dynamics of mass loss. High angular resolution studies of various types have shown that LPVs have a distinct core–halo structure. These have also shown that LPV images commonly exhibit a non-circular shape. The nature of this shape and its implications are yet to be understood.
Methods: Multi-telescope interferometric measurements taken with the Interferometric Optical Telescope Array (IOTA) provide imagery of the LPV Mira in the H-band. This wavelength region is well suited to studying mass loss given the low continuum opacity, which allows for emission to be observed over a very long path in the stellar atmosphere and envelope.
Results: The observed visibilities are consistent with a simple core-halo model to represent the central object and the extended molecular layers but, in addition, they demonstrate a substantial asymmetry. An analysis with image reconstruction software shows that the asymmetry is consistent with a localized absorbing patch. The observed opacity is tentatively associated with small dust grains, which will grow substantially during a multi-year ejection process. Spatial information along with a deduced dust content of the cloud, known mass loss rates, and ejection velocities provide evidence for the pulsational pumping of the extended molecular layers. The cloud may be understood as a spatially local zone of enhanced dust formation, very near to the pulsating halo. The observed mass loss could be provided by several such active regions around the star.
Conclusions: This result provides an additional clue for better understanding the clumpiness of dust production in the atmosphere of AGB stars. It is compatible with scenarios where the combination of pulsation and convection play a key role in the process of mass loss.

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Molecular gas in 21- and 30-μm sources: the 2-mm and 1.3-mm spectra of IRAS 21318+5631 and 22272+5435

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The carriers of the 21- and 30-μm emission features in infrared spectra of circumstellar envelopes are a long-standing enigma. In this paper, we present the results of molecular line observations toward two circumstellar envelopes exhibiting the 21- and/or 30-μm features, IRAS 21318+5631 and 22272+5435, aiming at investigating whether they have unusual gas-phase chemistry and searching for possible gas-phase precursor of the carriers of the two dust features. The spectra cover several discrete frequency ranges of 130–164 GHz and 216.5–273 GHz, resulting in a detection of 13 molecular species and isotopologues in each object. Rotation-diagram analysis is carried out to determine the molecular abundances, column densities, and excitation temperatures. We did not discover any molecular species that is unexpected in a normal C-rich star. Nevertheless, there exists subtle difference between their molecular abundances. IRAS 22272+5435 shows stronger SiC and HCN lines and weaker SiS lines than IRAS 21318+5631, presumably suggesting that this 21-μm source is more carbon rich and has experienced a more efficient dust formation. We discuss the potential implications of the results for the carriers of the 21-μm and 30-μm features.

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Are fulleranes responsible for the 21-μm feature?

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Recent detections of C_{60}, C_{70}, and C_{60}^{+} in space induced extensive studies of fullerene derivatives in circumstellar environments. As the promising fullerene sources, protoplanetary nebulae (PPNe) show a number of unidentified bands in their infrared spectra, among which a small sample exhibits an enigmatic feature at $\sim 21\ \mu$m. Hydrogenation of fullerenes can produce fulleranes emitting new infrared bands. In this paper, we investigate the possibility of fulleranes ($C_{60}H_m$) as the carrier of the 21-μm feature in terms of theoretical vibrational spectra of fulleranes. The evidences favoring and disfavoring the fullerane hypothesis are presented. We made an initial guess for the hydrogen coverage of $C_{60}H_m$ that may contribute to the 21-μm feature.

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The spectra of evolved stars at 20–25 GHz: tracing circumstellar chemistry during the asymptotic giant branch to planetary nebula transition

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We report an unbiased radio line survey towards the circumstellar envelopes of evolved stars at the frequency range from 20 to 25 GHz, aiming to obtain a more complete unbiased picture of the chemical evolution in the final stages of stellar evolution. The observation sample includes the asymptotic giant branch (AGB) star IRC +10°216, the proto-planetary nebulæ (PPNs) CRL 2688 and CRL 618, and the young planetary nebula (PN) NGC 7027, representing an evolutionary sequence spanning about 10,000 years. Rotational transitions from cyanopolyyne chains and inversion lines from ammonia are detected in the AGB star and PPNs, while the PN displays several recombination lines. The different spectral behaviors of these evolved stars clearly reflect the evolution of circumstellar chemistry during the AGB–PPN–PN transitions.

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Can the κ-distributed electron energies account for the intensity ratios of O II lines in photo-ionized gaseous nebulæ?

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A vexing puzzle in the study of planetary nebulæ and H II regions is that the plasma diagnostic results based on collisionally excited lines systematically differ from those based on recombination lines. A fairly speculative interpretation is the presence of nonthermal electrons with the so-called κ energy distributions, yet there is little observational evidence to verify or disprove this hypothesis. In this paper, we examine the influence of κ-distributed electrons on the emissivities of O II recombination lines using an approximate method, where the rate coefficients for a κ distribution are computed by summing Maxwellian–Boltzmann rate coefficients with appropriate weights. The results show that if invoking κ-distributed electrons, the temperatures derived from the [O III] (λ4959+λ5007)/λ4363 ratios could coincide with those estimated from the O II λ4649/λ4089 ratios. However, the estimated temperatures and κ values are not in agreement with those obtained through comparing the [O III] (λ4959+λ5007)/λ4363 ratios and the hydrogen recombination spectra, suggesting that the electron energy is unlikely to follow the κ-distributions over a global scale of the nebular regions. Nevertheless, based on this observation alone, we cannot definitely rule out the presence of κ-distributed electrons in some microstructures within nebulæ.

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Convection and spin-up during common envelope evolution: the formation of short-period double white dwarfs

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The formation channels and predicted populations of double-white dwarfs (DWDs) are important because a subset will evolve to be gravitational-wave sources and/or progenitors of Type Ia supernovæ. Given the observed population of short-period DWDs, we calculate the outcomes of common envelope evolution when convective effects are included. For each observed white dwarf in a DWD system, we identify all progenitor stars with an equivalent proto-WD core mass from a comprehensive suite of stellar evolution models. With the second observed white dwarf as the companion, we calculate the conditions under which convection can accommodate the energy released as the orbit decays, including (if necessary), how much the envelope must spin-up during the common envelope phase. The predicted post-CE final separations closely track the observed DWD orbital parameter space, further strengthening the view that convection is a key ingredient in common envelope evolution.

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Common envelope wind tunnel: range of applicability and self-similarity in realistic stellar envelopes

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Common envelope evolution, the key orbital tightening phase of the traditional formation channel for close binaries, is a multistage process that presents many challenges to the establishment of a fully descriptive, predictive theoretical framework. In an approach complementary to global 3D hydrodynamical modeling, we explore the range of applicability for a simplified drag formalism that incorporates the results of local hydrodynamic "wind tunnel" simulations into a semi-analytical framework in the treatment of the common envelope dynamical inspiral phase using a library of realistic giant branch stellar models across the low, intermediate, and high-mass regimes. In terms of a small number of key dimensionless parameters, we characterize a wide range of common envelope events, revealing the broad range of applicability of the drag formalism as well its self-similar nature across mass regimes and ages. Limitations arising from global binary properties and local structural quantities are discussed together with the opportunity for a general prescriptive application for this formalism.

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WIYN open cluster study – LXXXI. Caught in the act? The peculiar red giant NGC 2243-W2135

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High-dispersion spectra for giants through turnoff stars in the Li 6708 Å region have been obtained and analyzed

in the old, metal-deficient open cluster, NGC 2243. When combined with high dispersion data from other surveys, the cluster is found to contain a uniquely peculiar star at the luminosity level of the red clump. The giant is the reddest star at its luminosity, exhibits variability at a minimum 0.1 mag level on a timescale of days, is a single-lined, radial-velocity variable, and has $v \sin i$ between 35 and 40 km s^{-1}. In sharp contrast with the majority of the red giant cluster members, the star has a detectable Li abundance, potentially as high or higher than other giants observed to date while at or just below the boundary normally adopted for Li-rich giants. The observed anomalies may be indicators of the underlying process by which the giant has achieved its unusual Li abundance, with a recent mass transfer episode being the most probable within the currently limited constraints.

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Carbon-grain sublimation: a new top-down component of protostellar chemistry

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Earth's carbon deficit has been an outstanding problem in our understanding of the formation of our Solar System. A possible solution would be the sublimation of carbon grains at the so-called soot line ($\sim$ 300 K) early in the planet-formation process. Here, we argue that the most likely signatures of this process are an excess of hydrocarbons and nitriles inside the soot line, and a higher excitation temperature for these molecules compared to oxygen-bearing complex organics that desorb around the water snowline ($\sim$ 100 K). Such characteristics have been reported in the literature, for example, in Orion KL, although not uniformly, potentially due to differences in observational settings and analysis methods of different studies or related to the episodic nature of protostellar accretion. If this process is active, this would mean that there is a heretofore unknown component to the carbon chemistry during the protostellar phase that is acting from the top down – starting from the destruction of larger species – instead of from the bottom up from atoms. In the presence of such a top-down component, the origin of organic molecules needs to be re-explored.

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Early warning signals indicate a critical transition in Betelgeuse

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Critical transitions occur in complex dynamical systems, when the system dynamics undergoes a regime shift. These can often occur with little change in the mean amplitude of system response prior to the actual time of transition. The recent dimming and brightening event in Betelgeuse occurred as a sudden shift in the brightness and has been the subject of much debate. Internal changes or an external dust cloud have been suggested as reasons for this change in variability. We examine whether the dimming and brightening event of 2019–20 could be due to a critical transition in the pulsation dynamics of Betelgeuse, by studying the characteristics of the light curve prior to transition. We calculate the quantifiers hypothesized to rise prior to a critical transition for the light curve of Betelgeuse up to the

dimming event of 2019–20. These include the auto-correlation at lag-1, variance and the spectral coefficient calculated from detrended fluctation analysis (DFA), apart from two measures that quantify the recurrence properties of the light curve. Significant rises are confirmed using the Mann–Kendall trend test. We see a significant increase in all quantifiers ($p < 0.05$) prior to the dimming event of 2019–20. This suggests that the event was a critical transition related to the underlying nonlinear dynamics of the star. Together with results that suggests minimal change in $T_{\rm eff}$ and infra-red flux, a critical transition in the pulsation dynamics could be a possible reason for the unprecedented dimming of Betelgeuse. The rise in the studied quantifiers prior to the dimming event, supports this possibility.

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Standing on the shoulders of giants: new mass and distance estimates for Betelgeuse through combined evolutionary, asteroseismic, and hydrodynamical simulations with MESA

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We conduct a rigorous examination of the nearby red supergiant Betelgeuse by drawing on the synthesis of new observational data and three different modeling techniques. Our observational results include the release of new, processed photometric measurements collected with the space-based SMEI instrument prior to Betelgeuse's recent, unprecedented dimming event. Our theoretical predictions include self-consistent results from multi-timescale evolutionary, oscillatory, and hydrodynamic simulations conducted with the Modules for Experiments in Stellar Astrophysics (MESA) software suite. Significant outcomes of our modeling efforts include a precise prediction for the star's radius: 750^{+62}_{-30} $R_{\odot}$. In concert with additional constraints, this allows us to derive a new, independent distance estimate of 165^{+16}_{-8} pc and a parallax of $\pi = 6.06^{+0.31}_{-0.52}$ mas, in good agreement with *Hipparcos* but less so with recent radio measurements. Seismic results from both perturbed hydrostatic and evolving hydrodynamic simulations constrain the period and driving mechanisms of Betelgeuse's dominant periodicities in new ways. Our analyses converge to the conclusion that Betelgeuse's 388 day period is the result of pulsation in the fundamental mode, driven by the κ-mechanism. Grid-based hydrodynamic modeling reveals that the behavior of the oscillating envelope is mass-dependent, and likewise suggests that the non-linear pulsation excitation time could serve as a mass constraint. Our results corroborate recent conclusions that Betelgeuse is the outcome of a past merger. We place it definitively in the core helium-burning phase near the base of the red supergiant branch, and we report a present-day mass of 16.5–19 $M_{\odot}$ – slightly lower than typical literature values.

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Revisiting the impact of dust production from carbon-rich Wolf–Rayet binaries

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We present a dust spectral energy distribution (SED) and binary stellar population analysis revisiting the dust production rates (DPRs) in the winds of carbon-rich Wolf–Rayet (WC) binaries and their impact on galactic dust budgets. DustEM SED models of 19 Galactic WC "dustars" reveal DPRs of $\dot{M}_{\rm d} \sim 10^{-10}$–$10^{-6}$ M$_\odot$ yr^{-1} and carbon dust condensation fractions, χ_C, between 0.002–40%. A large (0.1–1.0 μm) dust grain size composition is favored for efficient dustars where $\chi_C \gtrsim 1$%. Results for dustars with known orbital periods verify a power-law relation between χ_C, orbital period, WC mass-loss rate, and wind velocity consistent with predictions from theoretical models of dust formation in colliding-wind binaries. We incorporated dust production into Binary Population and Spectral Synthesis (bpass) models to analyze dust production rates from WC dustars, asymptotic giant branch stars (AGBs), red supergiants (RSGs), and core-collapse supernovæ (SNe). BPASS models assuming constant star formation (SF) and a co-eval 10^6 M$_\odot$ stellar population were performed at low, Large Magellanic Cloud (LMC)-like, and solar metallicities ($Z = 0.001$, 0.008, and 0.020). Both constant SF and co-eval models indicate that SNe are net dust destroyers at all metallicities. Constant SF models at LMC-like metallicities show that AGB stars slightly outproduce WC binaries and RSGs by factors of 2–3, whereas at solar metallicites WC binaries are the dominant source of dust for ~ 60 Myr until the onset of AGBs, which match the dust input of WC binaries. Co-eval population models show that for "bursty" SF, AGB stars dominate dust production at late times ($t \gtrsim 70$ Myr).

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Fast and Automated Peak Bagging with Diamonds (famed)

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Stars of low and intermediate mass that exhibit oscillations may show tens of detectable oscillation modes each. Oscillation modes are a powerful tool to constrain the internal structure and rotational dynamics of the star, hence allowing one to obtain an accurate stellar age. The tens of thousands of solar-like oscillators that have been discovered thus far are representative of the large diversity of fundamental stellar properties and evolutionary stages available. Because of the wide range of oscillation features that can be recognized in such stars, it is particularly challenging to properly characterize the oscillation modes in detail, especially in light of large stellar samples. Overcoming this issue requires an automated approach, which has to be fast, reliable, and flexible at the same time. In addition, this approach should not only be capable of extracting the oscillation mode properties of frequency, linewidth, and amplitude from stars in different evolutionary stages, but also able to assign a correct mode identification for each of the modes extracted. Here we present the new freely available pipeline famed (Fast and AutoMated pEak bagging with Diamonds), which is capable of performing an automated and detailed asteroseismic analysis in stars ranging from the main sequence up to the core-helium-burning phase of stellar evolution. This, therefore, includes subgiant stars, stars evolving along the red giant branch (RGB), and stars likely evolving toward the early asymptotic giant

branch. In this paper, we additionally show how FAMED can detect rotation from dipolar oscillation modes in main sequence, subgiant, low-luminosity RGB, and core-helium-burning stars.

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It has to be cool: on supergiant progenitors of binary black hole mergers from common-envelope evolution

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Common-envelope (CE) evolution in massive binary systems is thought to be one of the most promising channels for the formation of compact binary mergers. In the case of merging binary black holes (BBHs), the essential CE phase takes place at a stage when the first BH is already formed and the companion star expands as a supergiant. We study which BH binaries with supergiant companions will evolve through and potentially survive a CE phase. To this end, we compute envelope binding energies from detailed massive stellar models at different evolutionary stages and metallicities. We make multiple physically extreme choices of assumptions that favor easier CE ejection as well as account for recent advancements in mass transfer stability criteria. We find that even with the most optimistic assumptions, a successful CE ejection in BH binaries is only possible if the donor is a massive convective-envelope giant, i.e. a red supergiant (RSG). The same is true for neutron star binaries with massive companions. In other words, pre-CE progenitors of BBH mergers are BH binaries with RSG companions. We find that due to its influence on the radial expansion of massive giants, metallicity has an indirect but a very strong effect on the chemical profile, density structure, and the binding energies of RSG envelopes. Our results suggest that merger rates from population synthesis models could be severely overestimated, especially at low metallicity. Additionally, the lack of observed RSGs with luminosities above $\log L \approx 5.6$–5.8, corresponding to stars with $M \gtrsim 40\ \mathrm{M}_{\odot}$, puts into question the viability of the CE channel for the formation of the most massive BBH mergers. Either such RSGs elude detection due to very short lifetimes, or they do not exist and the CE channel can only produce BBH systems with masses $\lesssim 50\ \mathrm{M}_{\odot}$. Finally, we discuss an alternative CE scenario, in which a partial envelope ejection is followed by a phase of possibly long and stable mass transfer.

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How to disentangle geometry and mass-loss rate from AGB-star spectral energy distributions. The case of EP Aqr

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Context: High-angular-resolution observations of asymptotic giant branch (AGB) stars often reveal non-spherical morphologies for the gas and dust envelopes.
Aims: We aim to make a pilot study to quantify the impact of different geometries (spherically symmetric, spiral-shaped, and disc-shaped) of the dust component of AGB envelopes on spectral energy distributions (SEDs), mass estimates, and subsequent mass-loss rate (MLR) estimates. We also estimate the error made on the MLR if the SED is fitted by an inappropriate geometrical model.

Methods: We use the three-dimensional Monte-Carlo-based radiative-transfer code RADMC-3D to simulate emission from dusty envelopes with different geometries (but fixed spatial extension). We compare these predictions with each other, and with the SED of the AGB star EP Aqr that we use as a benchmark since its envelope is disc-like and known to harbour spiral arms, as seen in CO.
Results: The SEDs involving the most massive envelopes are those for which the different geometries have the largest impact, primarily on the silicate features at 10 and 18 μm . These different shapes originate from large differences in optical depths. Massive spirals and discs appear akin to black bodies. Optically thick edge-on spirals and discs (with dust masses of 10^{-4} and 10^{-5} $M_\odot$) exhibit black-body SEDs that appear cooler than those from face-on structures and spheres of the same mass, while optically thick face-on distributions appear as warmer emission. We find that our more realistic models, combined spherical and spiral distributions, are 0.1 to 0.5 times less massive than spheres with similar SEDs. More extreme, less realistic scenarios give that spirals and discs are 0.01 to 0.05 times less massive than corresponding spheres. This means that adopting the wrong geometry for an AGB circumstellar envelope may result in a MLR that is incorrect by as much as one to two orders of magnitude when derived from SED fitting.

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VLTI/PIONIER reveals the close environment of the evolved system HD 101584

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Context: The observed orbital characteristics of post-asymptotic giant branch (post-AGB) and post-red giant branch (post-RGB) binaries are not understood. We suspect that the missing ingredients to explain them probably lie in the continuous interaction of the central binary with its circumstellar environment.
Aims: We aim at studying the circumbinary material in these complex systems by investigating the connection between the innermost and large-scale structures.
Methods: We perform high-angular resolution observations in the near-infrared continuum of HD 101584, which has a complex structure as seen at millimeter wavelengths with a disk-like morphology and a bipolar outflow due to an episode of strong binary interaction. To account for the complexity of the target we first perform an image reconstruction and use this result to fit a geometrical model to extract the morphological and thermal features of the environment.
Results: The image reveals an unexpected double-ring structure. We interpret the inner ring to be produced by emission from dust located in the plane of the disk and the outer ring to be produced by emission from dust that is located 1.6 [D / 1 kpc] au above the disk plane. The inner ring diameter (3.94 [D / 1 kpc] au), and temperature ($T = 1540 \pm 10$ K) are compatible with the dust sublimation front of the disk. The origin of the out-of-plane ring (with a diameter of 7.39 [D / 1 kpc] au and a temperature of 1014 ± 10 K) could be due to episodic ejection or a dust condensation front in the outflow.
Conclusion: The observed outer ring is possibly linked with the blue-shifted side of the large scale outflow seen by ALMA and is tracing its launching location to the central star. Such observations give morphological constraints on the ejection mechanism. Additional observations are needed to constrain the origin of the out-of-plane structure.

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Isotopic ratios in the red giant component of the recurrent nova T Coronæ Borealis

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We report the determination of abundances and isotopic ratios for C, O and Si in the photosphere of the red giant component of the recurrent nova T Coronæ Borealis from new 2.284–2.402-μm and 3.985–4.155-μm spectroscopy. Abundances and isotopic ratios in the photosphere may be affected by (i) processes in the red giant interior which are brought to the surface during dredge-up, (ii) contamination of the red giant, either during the common envelope phase of the binary evolution or by material synthesised in recurrent nova eruptions, or a combination of the two. We find that the abundances of C, O and Si are reasonably consistent with the expected composition of a red giant after first dredge-up, as is the ^{16}O/^{17}O ratio. The ^{28}Si/^{29}Si ratio is found to be 8.6 ± 3.0, and that for ^{28}Si/^{30}Si is 21.5 ± 3.0. The ^{12}C/^{13}C ratio (10 ± 2) is somewhat lower than expected for first dredge-up. The ^{16}O/^{18}O ratio (41 ± 3) is highly inconsistent with that expected either from red giant evolution (~ 550) or from contamination of the red giant by the products of a nova thermonuclear runaway. In particular the C and O isotopic ratios taken in combination are a puzzle. We urge confirmation of our results using spectroscopy at high resolution. We also encourage a thorough theoretical study of the effects on the secondary star in a recurrent nova system of contamination by ejecta having anomalous abundances and isotopic ratios.

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Available from https://arxiv.org/abs/2008.12150

Lithium in T Coronæ Borealis

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T Coronæ Borealis is a recurrent, symbiotic nova system currently in quiescence between its periodic $\simeq 80$ yr cycle of eruptions. Observations during inter-outburst epochs provide an opportunity to study properties of the accretion disk and the M red giant. Here we present new irradiated (blackbody veiling) models, incorporating modern molecular opacities and line lists, of spectra derived from high-resolution ($22,000 \lesssim R \lesssim 120,000$) optical échelle observations obtained at two epochs, one prior to and one post the 2015 rebrightening event at similar spectroscopic system phase. We find a lithium abundance in the secondary at both epochs to be comparable. The non-irradiated (classical) model atmospheres yield a lithium abundance, $A(\text{Li}) = 1.3 \pm 0.1$. The irradiated model (veiled) atmospheres, which are

likely a better representation of the system in which the white dwarf and accretion disk illuminate the red giant, give $A(\mathrm{Li}) = 2.4 \pm 0.1$.

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Nubi di polvere su Betelgeuse – dust clouds on Betelgeuse

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The circular orbital velocity v_c is calculated at the level of the photospheric radius of Betelgeuse, in order to know the order of magnitude of ejected dust clouds' velocity. Two months is the time required for a cloud ejected along the line of sight to reach the stellar limb, as observed during the great minimum of February 2020 (in phase with stellar main pulsation) and the secondary one of August 2020. By September 2020 the present maximum magnitude of Betelgeuse should be restored, if no others dust clouds are ejected. The secondary minimum reached in August 2020 is not pulsational, and it is due to a second dust cloud ejected along the line of sight. Text in Italian with one figure. The ATel #13982 is explained in details.

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On the absence of symbiotic stars in globular clusters

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Even though plenty of symbiotic stars (SySts) have been found in the Galactic field and nearby galaxies, not a single one has ever been confirmed in a Galactic globular cluster (GC). We investigate the lack of such systems in GCs for the first time by analysing 144 GC models evolved with the MOCCA code, which have different initial properties and are roughly representative of the Galactic GC population. We focus here on SySts formed through the wind-accretion channel, which can be consistently modelled in binary population synthesis codes. We found that the orbital periods of the majority of such SySts are sufficiently long ($\gtrsim 10^3$ d) so that, for very dense GC models, dynamical interactions play an important role in destroying their progenitors before the present day ($\sim$ 11–12 Gyr). In less dense GC models, some SySts are still predicted to exist. However, these systems tend to be located far from the central parts ($\gtrsim 70$ per cent are far beyond the half-light radius) and are sufficiently rare ($\lesssim 1$ per GC per Myr), which makes their identification rather difficult in observational campaigns. We propose that future searches for SySts in GCs should be performed in the outskirts of nearby low-density GCs with sufficiently long half-mass relaxation times and relatively large Galactocentric distances. Finally, we obtained spectra of the candidate proposed in ω Cen (SOPS IV e-94) and showed that this object is most likely not a SySt.

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Available from https://arxiv.org/abs/2004.05453
and from https://ui.adsabs.harvard.edu/abs/2020MNRAS.496.3436B/abstract

Review Papers

Weighing stars from birth to death: mass determination methods across the HRD

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The mass of a star is the most fundamental parameter for its structure, evolution, and final fate. It is particularly important for any kind of stellar archaeology and characterization of exoplanets. There exists a variety of methods in astronomy to estimate or determine it. In this review we present a significant number of such methods, beginning with the most direct and model-independent approach using detached eclipsing binaries. We then move to more indirect and model-dependent methods, such as the quite commonly used isochrone or stellar track fitting. The arrival of quantitative asteroseismology has opened a completely new approach to determine stellar masses and to complement and improve the accuracy of other methods. We include methods for different evolutionary stages, from the pre-main sequence to evolved (super)giants and final remnants. For all methods uncertainties and restrictions will be discussed. We provide lists of altogether more than 200 benchmark stars with relative mass accuracies between $[0.3, 2]\%$ for the covered mass range of $M \in [0.1, 16]$ $M_\odot$, 75% of which are stars burning hydrogen in their core and the other 25% covering all other evolved stages. We close with a recommendation how to combine various methods to arrive at a "mass-ladder" for stars.

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Available from https://arxiv.org/abs/2006.10868

Unveiling the structure and dynamics of red giants with asteroseismology

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The *Kepler* mission observed many thousands of red giants. The long time series, some as long as the mission itself, have allowed us to study red giants with unprecedented detail. Given that red giants are intrinsically luminous, and hence can be observed from very large distances, knowing the properties of red giants, in particular ages, is of immense value for studies of the formation and evolution of the Galaxy, an endeavor known as "Galactic archæology". In this article we review what we have learned about red giants using asteroseismic data. We start with the properties of the power spectrum and move on to internal structure and dynamics of these stars; we also touch upon unsolved issues in red-giant asteroseismology and the prospects of making further progress in understanding these stars.

Published in Frontiers in Astronomy and Space Sciences
Available from https://arxiv.org/abs/2006.14643
and from https://doi.org/10.3389/fspas.2020.00044

Announcements

Research primers

Dear All

The IAU commission H3 'Planetary Nebulæ' would like to make a request.

Research into planetary nebulæ covers an extraordinary wide range of topics. This can be hard especially for beginning research students, who are expected to learn about stellar evolution, stellar winds, hydro-dynamics, photo-ionization, abundances, dust, binary interaction, etc, and may across observations ranging from X-ray to radio and everything in between. To make the field more accessible, we would like to collect some research primers: brief introductions into a topic of relevance which explain the topic at a level accessible to early postgraduate students and have pointers at current research. They can be found at

https://www.iau.org/science/scientific_bodies/commissions/H3/info/primers/

So far there are three such primers, two specifically written for this purpose and one published elsewhere.

1. Planetary nebulæ and how to find them – Quentin Parker
2. Central stars of planetary nebulæ and related objects – Marcelo M. Miller Bertolami
3. Nebular spectroscopy: a guide on H II regions and planetary nebulæ – Manuel Peimbert, Antonio Peimbert and Gloria Delgado-Inglada

If you are interested in contributing a primer in your area of expertise, we would love to hear from you. Please get in touch (email albert.zijlstra@manchester.ac.uk) to discuss your ideas. It is an excellent way to support our young researchers.

See also https://www.iau.org/science/scientific_bodies/commissions/H3/info/primers/

Second dust cloud on Betelgeuse

Following the discussions of February 2020 AGB dedicated on Betelgeuse's dimming, it is worth to consider the recent observations of that star.

ATel #13982; Costantino Sigismondi (ICRA/Sapienza University of Rome and ITIS G. Ferraris, Rome), Wolfgang Vollmann (AAVSO/BAV), Otmar Nickel (University of Mainz and AAVSO/BAV), Alexandre Amorim (NEOA-JBS, AAVSO), Rod Stubbings (AAVSO), Fabio Mariuzza (AAVSO), Paolo Ochner (University of Padua and Asiago Astrophysical Observatory), Margarita Karovska (Harvard–Smithsonian Center for Astrophysics), Luigi Bordoni (Sapienza University of Rome and Italian Physical Society), Remo Ruffini (ICRANet Pescara), Cesare Barbieri (University of Padua) on 30 Aug 2020; 22:30 UT Credential Certification: Costantino Sigismondi (sigismondi@icra.it)

Subjects: Optical, Star, Transient, Variables

The photometry of Betelgeuse is continuing to give us surprises. It seems like a second dust cloud ejected by the star is passing over its photosphere along our line of sight. As mentioned in ATel #13901 after a unusual short-lived maximum around 0.4 magnitude (ATel #13601) reached in April/May 2020 the star began again to fade in July

2020. After reaching a secondary minimum after August 3rd, 2020 at magnitude $V = +1.0$, on August 27, 2020 the star gained 0.3 magnitudes, recovering magnitude $V = +0.7$. Measurements with DSLR differential V photometry (W. Vollmann), also made in daytime (O. Nickel), showed this behavior within ± 0.04 magnitudes of typical errorbar. Naked eye observations in twilight, always with airmass corrections, of A. Amorim (Brazil), R. Stubbings (Australia), F. Mariuzza (Italy) and C. Sigismondi (Italy) confirmed the attained maximum at magnitude 0.4, and the following fading phase. The interpretation of these observations suggests the presence of a second dust cloud, following the great one (in phase with the main pulsational period of 1.2 years) which determined the deep minimum of Betelgeuse in December 2019–February 2020. The level of the present maximum luminosity (+0.4 mag) of Betelgeuse should be recovered by September 2020, if no new clouds will appear on the line of sight.

See also http://www.astronomerstelegram.org/?read=13982