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Editors: Jacco van Loon, Ambra Nanni and Albert Zijlstra

Editorial

Dear Colleagues,

It is our pleasure to present you the 291st issue of the AGB Newsletter. A little later than usual, due to commitments on the paid job.

Talking of which, don't forget the 15th October deadline for ESO Fellowship applications! Or apply for one of the postdoc positions at the IAC.

Also consider submitting your Ph.D. thesis for the IAU Thesis Prize – see the information at the back of the Newsletter.

We received a suggestion for Food for Thought – see below. We look forward to your reactions, or further suggestions.

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

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

Food for Thought

This month's thought-provoking statement is:

Carbon stars often have emission in Hα – why, on some occasions, is this emission line split?

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

Identifying low-amplitude pulsating stars through microlensing observations

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One possibility for detecting low-amplitude pulsational variations is through gravitational microlensing. During a microlensing event, the temporary brightness increase leads to improvement in the signal-to-noise ratio, and thereby better detectability of pulsational signatures in light curves. We explore this possibility under two primary considerations. The first is when the standard point-source and point-lens approximation applies. In this scenario, dividing the observed light curve by the best-fitted microlensing model leads to residuals that result in pulsational features with improved uncertainties. The second is for transit events (single lens) or caustic crossing (binary lens). The point-source approximation breaks down, and residuals relative to a simple best-fitted microlensing model display more complex behavior. We employ a Monte-Carlo simulation of microlensing of pulsating variables toward the Galactic bulge for the surveys of OGLE and of KMTNet. We demonstrate that the efficiency for detecting pulsational signatures with intrinsic amplitudes of < 0.25 mag during single and binary microlensing events, at differences in χ^2 of $\Delta\chi^2 > 350$, is ~ 50–60%. The maximum efficiency occurs for pulsational periods $P \simeq 0.1$–0.3 days. We also study the possibility that high-magnification microlensing events of non-radially pulsating stars (NRPs) could be misinterpreted as planetary or binary microlensing events. We conclude that small asymmetric features around lightcurve peaks due to stellar pulsations could be misdiagnosed with crossing (or passing close to) small caustic curves.

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Spectroscopic and seismic analysis of red giants in eclipsing binaries discovered by *Kepler*

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Eclipsing binaries (EBs) are unique targets for measuring accurate stellar properties and constraining stellar evolution models. In particular, it is possible to measure masses and radii at the few percent level for both components of a

double-lined spectroscopic EB (SB2-EB). On the one hand, detached EBs hosting at least one star with detectable solar-like oscillations constitute ideal test objects to verify the ability of ensemble asteroseismology to derive stellar properties. On the other hand, the oscillations and surface activity of stars that belong to EBs offer unique information about the evolution of binary systems. This paper builds upon previous works dedicated to red giant stars (RG) in EBs; so far 20 known systems have been discovered by the NASA *Kepler* mission. We report the discovery of 16 RGs in EBs, which are also from the *Kepler* data, leading to a total of 36 confirmed RG stars in EBs from the original *Kepler* mission. This new sample includes three SB2-EBs with oscillations, resulting in a total of 14 known SB2-EBs with an oscillating RG component. This sample also includes six close systems in which the RG display a clear surface activity and complete oscillation suppression. Based on dedicated high-resolution spectroscopic observations (Apache Point Observatory, Observatoire de Haute Provence), we focus on three main aspects. Firstly, from the extended sample of 14 SB2-EBs, we confirm that the simple application of the asteroseismic scaling relations to RGs overestimates masses and radii of RGs by about 15% and 5%. This bias can be reduced by employing either new asteroseismic reference values for RGs or model-based corrections of the asteroseismic parameters. Secondly, we confirm that close binarity leads to a high level of photometric modulation (up to 10%) and a suppression of solar-like oscillations. In particular, we show that it reduces the lifetime of radial modes by a factor of up to 10. Thirdly, we use our 16 new systems to complement previous observational studies that aimed to constrain tidal dissipation in interacting binaries. We confirm the important role of the equilibrium tide in binary evolution, but we also identify systems with circular orbits despite relatively young ages, which suggests the need to explore complementary tidal dissipation mechanisms in the future. Finally, as a by-product, we report the measurements of mass, radius, and age of three M-dwarf companion stars.

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Seismic constraints on the internal structure of evolved stars: from high-luminosity RGB to AGB stars

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The space-borne missions CoRoT and *Kepler* opened up a new opportunity to better understand stellar evolution by probing stellar interiors with unrivalled high-precision photometric data. *Kepler* has observed stellar oscillation during four years, which gave access to excellent frequency resolution, making it possible to decipher the oscillation spectrum of evolved red giant branch and asymptotic giant branch stars.
The internal structure of stars on the upper parts of both the red and asymptotic giant branches is poorly constrained, which makes the distinction between red and asymptotic giants difficult. We perform a thorough seismic analysis to address the physical conditions inside those stars and to distinguish them.
We take advantage of what we have learnt from less evolved stars. We study the oscillation mode properties of $\sim 2\,000$ evolved giants in a model described by the asymptotic pressure-mode pattern of red giants that includes the signature of the helium second-ionisation zone. Mode identification is performed with a maximum cross-correlation method. Then, the modes are fitted with Lorentzian functions following a maximum likelihood estimator technique.
We derive a large set of seismic parameters of evolved red and asymptotic giants. We extracted the mode properties up to the degree $\ell = 3$ and investigated their dependence on stellar mass, metallicity, and evolutionary status. We identify a clear difference in the signature of the helium second-ionisation zone between red and asymptotic giants. We also detect a clear shortage of the energy of $\ell = 1$ modes after the core-He-burning phase. Furthermore, we notice that the mode damping observed on the asymptotic giant branch is similar to that observed on the red giant branch. We highlight that the signature of the helium second-ionisation zone varies with stellar evolution. This provides us with a physical basis for distinguishing red giant branch stars from asymptotic giants. Here, our investigation of stellar

oscillations allows us to constrain the physical processes and the key events that occur during the advanced stages of stellar evolution, with emphasis on the ascent along the asymptotic giant branch including the asymptotic giant branch bump.

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Lithium in red giants: the roles of the He-core flash and the luminosity bump

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Lithium abundances for red giants in the GALAH DR3 survey are studied. The rare examples of Li-enriched stars with abundances $A(\mathrm{Li}) \geq 1.5$ are confirmed to be He-core burning stars belonging to or evolved from the red clump with similar masses and metallicity: $M \simeq 1.1 \pm 0.2$ $\mathrm{M}_{\odot}$ and $[\mathrm{Fe/H}] \simeq -0.3 \pm 0.3$. Li enrichment over the Li abundance present in a star's predecessor at the tip of the red giant branch likely occurs in all these red clump stars. Examination of the elemental abundances (C to Eu) in the GALAH catalogue shows no anomalous abundances in red clump giants and, in particular, no dependence on the Li abundance, which ranges over at least five dex. Lithium synthesis is attributed to the He-core flash occurring in stars at the tip of the red giant branch. Models from the Modules for Experiments in Stellar Astrophysics (MESA) match the observed evolution of these stars along the red giant branch and to the red clump but only at the low effective temperature end of the observed spread of red clump giants. Run of Li abundance on the red giant branch is fairly well reproduced by MESA models. A speculation is presented that the series of He-core flashes not only leads to ^{7}Li synthesis from a star's internal reservoir of ^{3}He but also may lead to internal restructuring leading to the observed effective temperature spread of red clump stars at about a constant luminosity. Giants exhibiting marked Li enrichments are not found at other evolutionary phases and, in particular, not directly associated with the luminosity bump on the red giant branch for which the Li abundance increase does not exceed 0.3 dex.

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Morphological study of the nested planetary nebula Hubble 12

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We present a visible-infrared imaging study of young planetary nebula (PN) Hubble 12 (Hb 12; PN G111.8−02.8) obtained with *Hubble* Space Telescope (HST) archival data and our own Canada–France–Hawai'i Telescope (CFHT) measurements. Deep HST and CFHT observations of this nebula reveal three pairs of bipolar structures and an arc-shaped filament near the western waist of Hb 12. The existence of nested bipolar lobes together with the presence of H_2 knots suggests that these structures originated from several mass-ejection events during the pre-PN phase. To

understand the intrinsic structures of Hb 12, a three-dimensional model enabling the visualisation of this PN at various orientations was constructed. The modelling results show that Hb 12 may resemble other nested hourglass nebulae, such as Hen 2-320 and M 2-9, suggesting that this type of PN may be common and the morphologies of PNs are not so diverse as is shown by their visual appearances. The infrared spectra show that this PN has a mixed chemistry. We discuss the possible material that may cause the unidentified infrared emissions. The analyses of the infrared spectra and the spectral energy distribution suggest the existence of a cool companion in the nucleus of this object.

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Observations of the Bright Star in the globular cluster 47 Tucanæ (NGC 104)

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The Bright Star in the globular cluster 47 Tucanæ (NGC 104) is a post-AGB star of spectral type B8 III. The ultraviolet spectra of late-B stars exhibit a myriad of absorption features, many due to species unobservable from the ground. The Bright Star thus represents a unique window into the chemistry of 47 Tuc. We have analyzed observations obtained with the Far Ultraviolet Spectroscopic Explorer (FUSE), the Cosmic Origins Spectrograph (COS) aboard the *Hubble* Space Telescope, and the MIKE Spectrograph on the *Magellan* Telescope. By fitting these data with synthetic spectra, we determine various stellar parameters ($T_{\rm eff} = 10,850 \pm 250$ K, $\log g = 2.20 \pm 0.13$) and the photospheric abundances of 26 elements, including Ne, P, Cl, Ga, Pd, In, Sn, Hg, and Pb, which have not previously been published for this cluster. Abundances of intermediate-mass elements (Mg through Ga) generally scale with Fe, while the heaviest elements (Pd through Pb) have roughly solar abundances. Its low C/O ratio indicates that the star did not undergo third dredge-up and suggests that its heavy elements were made by a previous generation of stars. If so, this pattern should be present throughout the cluster, not just in this star. Stellar-evolution models suggest that the Bright Star is powered by a He-burning shell, having left the AGB during or immediately after a thermal pulse. Its mass (0.54 ± 0.16 $M_\odot$) implies that single stars in 47 Tuc lose 0.1–0.2 $M_\odot$ on the AGB, only slightly less than they lose on the RGB.

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ATOMIUM: Halide molecules around the S-type AGB star W Aquilæ

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S-type asymptotic giant branch (AGB) stars are thought to be intermediates in the evolution of oxygen- to carbon-rich AGB stars. The chemical compositions of their circumstellar envelopes are also intermediate, but have not been

studied in as much detail as their carbon- and oxygen-rich counterparts. We aim to determine the abundances of AlCl and AlF from rotational lines, which have been observed for the first time towards an S-type AGB star, W Aql. In combination with models based on PACS observations, we aim to update our chemical kinetics network based on these results. We analyse ALMA observations towards W Aql of AlCl in the ground and first two vibrationally excited states and AlF in the ground vibrational state. Using radiative transfer models, we determine the abundances and spatial abundance distributions of $Al^{35}Cl$, $Al^{37}Cl$, and AlF. We also model HCl and HF emission and compare these models to PACS spectra to constrain the abundances of these species. AlCl is found in clumps very close to the star, with emission confined within $0\farcs1$ of the star. AlF emission is more extended, with faint emission extending $0\farcs2$ to $0\farcs6$ from the continuum peak. We find peak abundances, relative to H_2, of 1.7×10^{-7} for $Al^{35}Cl$, 7×10^{-8} for $Al^{37}Cl$ and 1×10^{-7} for AlF. From the PACS spectra, we find abundances of 9.7×10^{-8} and $\leq 10^{-8}$, relative to H_2, for HCl and HF, respectively. The AlF abundance exceeds the solar F abundance, indicating that fluorine synthesised in the AGB star has already been dredged up to the surface of the star and ejected into the circumstellar envelope. From our analysis of chemical reactions in the wind, we conclude that AlF may participate in the dust formation process, but we cannot fully explain the rapid depletion of AlCl seen in the wind.

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Proper Plasma Analysis Practice (PPAP), an integrated procedure of extinction correction and plasma diagnostics: a demo with an HST/WFC3 image set of NGC 6720

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In this work, we propose a proper plasma analysis practice (PPAP), an updated procedure of plasma diagnostics in the era of spatially resolved spectroscopy. In particular, we emphasize the importance of performing both of the extinction correction and the direct method of plasma diagnostics simultaneously as an integrated process. This approach is motivated by the reciprocal dependence between critical parameters in these analyses, which can be resolved by iteratively seeking a converged solution. The use of PPAP allows us to eliminate unnecessary assumptions that prevent us from obtaining an exact solution at each element of the spectral imaging data. Using a suite of *Hubble* Space Telescope/WFC3 narrowband images of the planetary nebula, NGC 6720, we validate PPAP by (1) simultaneously and self-consistently deriving the extinction, $c(\mathrm{H}\beta)$, and electron density/temperature distribution, (n_e([S II]), T_e([N II])), maps that are consistent with each other, and (2) obtaining identical metal abundance distribution maps, ($n(\mathrm{N}^+)/n(\mathrm{H}^+)$, $n(\mathrm{S}^+)/n(\mathrm{H}^+)$), from multiple emission line maps at different wavelengths/transition energies. We also determine that the derived $c(\mathrm{H}\beta)$ consists both of the interstellar medium and circumsource components and that the ionized gas-to-dust mass ratio in the main ring is at least 437 and as high as about 1600. We find that, unless we deliberately seek self-consistency, uncertainties at tens of % can easily arise in outcomes, making it impossible to discern actual spatial variations that occurs at the same level, defeating the purpose of conducting spatially resolved spectroscopic observations.

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First deep images catalogue of extended IPHAS PNe

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We present the first instalment of a deep imaging catalogue containing 58 True, Likely and Possible extended PNe detected with the *Isaac Newton* Telescope Photometric Hα Survey (IPHAS). The three narrow-band filters in the emission lines of Hα, [N II] λ6584 Å and [O III] λ5007 Å used for this purpose allowed us to improve our description of the morphology and dimensions of the nebulæ. In some cases even the nature of the source has been reassessed. We were then able to unveil new macro-and micro-structures, which will without a doubt contribute to a more accurate analysis of these PNe. It has been also possible to perform a primary classification of the targets based on their ionization level. A Deep Learning classification tool has also been tested. We expect that all the PNe from the IPHAS catalogue of new extended planetary nebulæ will ultimately be part of this deep Hα, [N II] and [O III] imaging catalogue.

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Maser emission from the CO envelope of the asymptotic giant branch star W Hydræ

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Observation of CO emission around asymptotic giant branch (AGB) stars is the primary method to determine gas mass-loss rates. While radiative transfer models have shown that molecular levels of CO can become mildly inverted, causing maser emission, CO maser emission has yet to be confirmed observationally. High-resolution observations of the CO emission around AGB stars now have the brightness temperature sensitivity to detect possible weak CO maser emission. We used high angular resolution observations taken with the Atacama Large Millimeter/submillimeter Array (ALMA) to observe the small-scale structure of CO $J = 3$–2 emission around the oxygen-rich AGB star W Hya. We find CO maser emission amplifying the stellar continuum with an optical depth $\tau \approx -0.55$. The maser predominantly amplifies the limb of the star because CO $J = 3$–2 absorption from the extended stellar atmosphere is strongest towards the centre of the star. The CO maser velocity corresponds to a previously observed variable component of high-frequency H_2O masers and with the OH maser that was identified as the amplified stellar image. This implies that the maser originates beyond the acceleration region and constrains the velocity profile since we find the population inversion primarily in the inner circumstellar envelope. We find that inversion can be explained by the radiation field at 4.6 μm and that the existence of CO maser emission is consistent with the estimated mass-loss rates for W Hya. However, the pumping mechanism requires a complex interplay between absorption and emission lines in the extended

atmosphere. Excess from dust in the circumstellar envelope of W Hya is not sufficient to contribute significantly to the required radiation field at 4.6 μm. The interplay between molecular lines that cause the pumping can be constrained by future multi-level CO observations.

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The 3.3-μm infrared emission feature: observational and laboratory constraints on Its carrier

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We examine the self-consistency of laboratory and observational data for potential carriers of the 3.3-μm infrared emission feature (IEF), a member of the ubiquitous family of strong interstellar IEFs at 3.3, 3.4, 6.2, 7.7, 8.6, 11.2, and 12.7 μm. Previous studies have shown that most Galactic sources (reflection nebulæ, H II regions, and planetary nebulæ) show 3.3-μm IEFs displaying similar central wavelengths, FWHM, and profiles. Our study is focused on the band profile designated as Class A, the most prevalent of four classes of observed band profiles. In contrast to the observations, laboratory spectra for gas phase polycyclic aromatic hydrocarbons (PAHs), the widely assumed carriers of the IEFs, display central wavelength shifts, widths, and profiles that vary with temperature and PAH size. We present an extrapolation of the laboratory band shifts and widths for smaller PAHs ($\leq$ 32 carbon atoms) to the larger PAHs ($>$ 50 carbon atoms) that are thought to be the IEF carriers. The extrapolation leads to tight constraints on the sizes of the putative PAH carriers. Reconciling the observations with the implications of the laboratory spectra pose a significant challenge to the PAH and other IEF carrier hypotheses.

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ALMA observations of W Hya: impact of missing baselines

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The lack of short baselines, referred to as short-spacing problem (SSP), is a well-known limitation of the performance of radio interferometers, causing a reduction of the detected flux at increasing angular distances from the target. The very large number of antennas operated in the Atacama Large Millimeter/sub-millimeter Array (ALMA) generates situations for which the impact of the SSP takes a complex form, not simply measurable by a single number, such as the Maximal Recoverable Scale. In particular extended antenna configurations, complemented by a small group of closeby antennas at the centre of the array, may result in a double-humped baseline distribution with a significant gap between the two groups. In such cases one should adopt as effective maximal recoverable scale that associated with the extended array and use only the central array to recover missing flux, as one would do with single dish or ACA (Atacama Compact Array) observations. The impact of the missing baselines can be very important and may easily be underestimated, or even overlooked. The present study uses archival observations of the ^{29}SiO(8–7) line emission of AGB star W Hya as an illustration. A critical discussion of the reliability of the observations away from the star is presented together with comments of a broader scope. Properties of the circumstellar envelope of W Hya within 15 au from the star, not mentioned in the published literature, are briefly described and compared with R Dor, an AGB star having properties very similar to W Hya.

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Keplerian disks and outflows in post-AGB stars: AC Herculis, 89 Herculis, IRAS 19125+0343, and R Scuti

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Context: There is a class of binary post-AGB stars with a remarkable near-infrared excess that are surrounded by Keplerian or quasi-Keplerian disks and extended outflows composed of gas escaping from the disk. The Keplerian dynamics had been well identified infour cases, namely the Red Rectangle, AC Her, IW Car, and IRAS 08544−4431. In these objects, the mass of the outflow represents $\sim 10\%$ of the nebular mass, the disk being the dominant component of the nebula.
Aims: We aim to study the presence of rotating disks in sources of the same class in which the outflow seems to be the dominant component.
Methods: We present interferometric NOEMA maps of ^{12}CO and ^{13}CO $J = 2$–1 in 89 Her and ^{12}CO $J = 2$–1 in AC Her, IRAS 19125+0343, and R Sct. Several properties of the nebula are obtained from the data and model fitting, including the structure, density, and temperature distributions, as well as the dynamics. We also discuss the uncertainties on the derived values.
Results: The presence of an expanding component in AC Her is doubtful, but thanks to new maps and models, we estimate an upper limit to the mass of this outflow of $\lesssim 3 \times 10^{-5}$ M$_\odot$, that is, the mass of the outflow is $\lesssim 5\%$ of the total nebular mass. For 89 Her, we find a total nebular mass of 1.4×10^{-2} M$_\odot$, of which $\sim 50\%$ comes from an hourglass-shaped extended outflow. In the case of IRAS 19125+0343, the nebular mass is 1.1×10^{-2} M$_\odot$, where the outflow contributes $\sim 70\%$ of the total mass. The nebular mass of R Sct is 3.2×10^{-2} M$_\odot$, of which $\sim 75\%$ corresponds to a very extended outflow that surrounds the disk.
Conclusions: Our results for IRAS 19125+0343 and R Sct lead us to introduce a new subclass of binary post-AGB stars, for which the outflow is the dominant component of the nebula. Moreover, the outflow mass fraction found in AC Her is smaller than those found in other disk-dominated binary post-AGB stars. 89 Her would represent an intermediate case between both subclasses.

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Stellar evolution models with entropy-calibrated mixing-length parameter: application to red giants

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We present evolutionary models for solar-like stars with an improved treatment of convection that results in a more accurate estimate of the radius and effective temperature. This is achieved by improving the calibration of the mixing-length parameter, which sets the length scale in the 1D convection model implemented in the stellar evolution code. Our calibration relies on the results of 2D and 3D radiation hydrodynamics simulations of convection to specify the value of the adiabatic specific entropy at the bottom of the convective envelope in stars as a function of their effective

temperature, surface gravity, and metallicity. For the first time, this calibration is fully integrated within the flow of a stellar evolution code, with the mixing-length parameter being continuously updated at run-time. This approach replaces the more common, but questionable, procedure of calibrating the length scale parameter on the Sun, and then applying the solar-calibrated value in modelling other stars, regardless of their mass, composition, and evolutionary status. The internal consistency of our current implementation makes it suitable for application to evolved stars, in particular to red giants. We show that the entropy calibrated models yield a revised position of the red giant branch that is in better agreement with observational constraints than that of standard models.

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Binary central stars of planetary nebulæ identified with *Kepler*/K2

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We present the identification of 34 likely binary central stars (CSs) of planetary nebulæ (PNe) from *Kepler*/K2 data, seven of which show eclipses. Of these, 29 are new discoveries. Two additional CSs with more complicated variability are also presented. We examined the light curves of all 'possible', 'likely' and 'true' PNe in every *Kepler*/K2 campaign (0 through 19) to identify CS variability that may indicate a binary CS. For Campaigns 0, 2, 7, 15, and 16 we find 6 likely or confirmed variables among 21 PNe. Our primary effort, though, was focused on Campaign 11 which targeted a Galactic bulge field containing approximately 183 PNe, in which we identified 30 candidate variable CSs. The periods of these variables range from 2.3 h to 30 d, and based on our analysis, most are likely to be close binary star systems. We present periods and preliminary classifications (eclipsing, double degenerate, or irradiated systems) for the likely binaries based on light curve shape. From our total sample of 204 target PNe, with a correction for incompleteness due to magnitude limits, we calculate a binary fraction of PN central stars to be 20.7 percent for all the observed PNe, or 23.5 percent if we limit our sample only to 'true' PNe. However these fractions are almost certainly lower limits due to the large angular size of the *Kepler* pixels, which leads to reduced sensitivity in detecting variability, primarily as a result of dilution and noise from the nebula and neighbouring stars. We discuss the binary population of CSs based on these results as part of the total known sample of close binary CSs.

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A grid of core-collapse supernova remnant models. I. The effect of wind-driven mass loss

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Massive stars can shed material via steady, line-driven winds, eruptive outflows, or mass transfer onto a binary companion. In the case of single stars, the mass is deposited by the stellar wind into the nearby environment. After the massive star explodes, the stellar ejecta interact with this circumstellar material (CSM), oftentimes resulting in bright X-ray line emission from both the shock-heated CSM and ejecta. The amount of material lost by the progenitor, the mass of ejecta, and its energetics all impact the bulk spectral characteristics of this X-ray emission. Here we present a grid of core-collapse supernova remnant models derived from models for massive stars with zero-age main-sequence masses of $\sim$ 10–30 $M_\odot$ evolved from the pre-main-sequence stage with wind-driven mass loss. Evolution is handled by a multistage pipeline of software packages. First, we use MESA (Modules for Experiments in Stellar Astrophysics) to evolve the progenitors from pre-main-sequence to iron core collapse. We then use the Supernova Explosion Code (SNEC) to explode the mesa models, and we follow them for the first 100 days following core collapse. Finally, we couple the SNEC output, along with the CSM generated from MESA mass-loss rates, into the cosmic-ray hydrodynamics code to model the remnant phase to 7000 yr after core collapse. At the end of each stage, we compare our outputs with those found in the literature, and we examine any qualitative and quantitative differences in the bulk properties of the remnants and their spectra based on the initial progenitor mass, as well as mass-loss history.

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Void-defect induced magnetism and structure change of carbon material – II: Graphene molecules

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Void-defect is a possible origin of ferromagnetic feature on pure carbon materials. In our previous paper, void-defect on graphene-nanoribbon show highly polarized spin configuration. In this paper, we studied cases for graphene molecules by quantum theory, by astronomical observation and by laboratory experiment. Model molecules for the density functional theory are graphene molecules of C_{23} and C_{53} induced by a void-defect. They have carbon pentagon ring within a hexagon network. Single void has three radical carbons, holding six spins. Those spins make several spin-states, which affects to molecular structure and molecular vibration, finally to infrared spectrum. The stable spin state was triplet, not singlet. This suggests magnetic pure carbon molecule. It was a surprise that those molecules show close infrared spectrum with astronomically observed one, especially observed on carbon rich planetary nebulæ. We could assign major band at 18.9 μm, and sub-bands at 6.6, 7.0, 7.6, 8.1, 8.5, 9.0 and 17.4 μm. Also, calculated spectrum roughly coincides with that of laboratory experiment by the laser-induced carbon plasma, which is an analogy of cosmic carbon creation in interstellar space.

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Void-defect induced magnetism and structure change of carbon material – III: Hydrocarbon molecules

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Void-defect induced magnetism of graphene molecule was recently reported in our previous paper of this series study. This paper investigated the case of hydrogenated graphene molecule, in chemical term, polycyclic aromatic hydrocarbon (PAH). Molecular infrared spectrum obtained by density functional theory was compared with astronomical observation. Void-defect on PAH caused serious structure change. Typical example of $C_{23}H_{12}$ had two carbon pentagon rings among hexagon networks. Stable spin state was non-magnetic singlet state. This is contrary to pure carbon case of C_{23}, which show magnetic triplet state. It was discussed that hydrogen played an important role to diminish magnetism by creating an SP3-bond among SP2-networks. Such a structure change affected molecular vibration and finally to photoemission spectrum in infrared region. The dication-$C_{23}H_{12}$ showed featured bands at 3.2, 6.3, 7.7, 8.6, 11.2, and 12.7 μm. It was surprising that those calculated bands coincided well with astronomically observed bands in many planetary nebulæ. To confirm our study, large size molecule of $C_{53}H_{18}$ was studied. Calculation reproduced again similar astronomical bands. Also, small size molecule of $C_{12}H_8$ showed good coincidence with the spectrum observed for young stars. This paper would be the first report to indicate the specific PAH in space.

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The symbiotic binary ZZ CMi: intranight variability and suggested outbursting nature

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We present photometric and spectral observations of the symbiotic star ZZ CMi. We detect intranight variability – flickering and smooth variations in U band. The amplitude of the flickering is about 0.10–0.20 mag in U band. In the B band, the variability is lower, with amplitude < 0.03 mag. We also detect variability in the Hα and Hβ emission lines, and find an indication for outflow with velocity of about 120–150 km s^{-1}.
The results indicate that ZZ CMi is an accretion-powered symbiotic containing an M4–M6 III cool component with an white dwarf resembling recurrent novæ and jet-ejecting symbiotic stars.
The data are are available at onlinelibrary.wiley.com/doi/10.1002/asna.202113975 or upon request to the authors (rkz@astro.bas.bg).
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The interstellar medium toward the Galactic Center source 2MASS J17470898−2829561

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We describe and discuss remarkable infrared spectra, covering key portions of the 2–5-μm wavelength interval, of the probable OH/IR supergiant 2MASS J17470898−2829561 (2M1747), located in direction of the Sgr B molecular cloud complex within the Central Molecular Zone (CMZ) of the Galaxy. This star was originally singled out for examination based on its suitability for spectroscopy of lines of H_3^+ in the CMZ. Analysis of the spectra shows that 2M1747 is deeply embedded within Sgr B1, with $A_V \gtrsim 100$ mag, making it the only star within Sgr B for which infrared spectra have been obtained at present, and thereby a unique infrared probe of the dense interstellar medium within the CMZ. Despite the high extinction, spectra of 2M1747 reveal a veiled photosphere in the K band and circumstellar gas in the M band, giving clues as to its nature. Its 3.5–4.0-μm spectrum contains the strongest absorption lines of H_3^+ observed toward any object to date. The 4.5–4.8-μm spectrum has impressively deep and wide absorption lines of interstellar CO, most of which arise in dense gas within Sgr B1. The 3–5-μm spectrum also contains several solid-state absorption features, which are characteristic of both dense and diffuse clouds, and which raise questions about the identifications of some of these features. We discuss the nature of the star, the extinction to it, the extinction law for dust in the CMZ, and the identifications of the various solid-state features and where they are produced along this complex line of sight.

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Absorption lines in the 0.91–1.33-μm spectra of red giants for measuring abundances of Mg, Si, Ca, Ti, Cr, and Ni

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Red giants show a large number of absorption lines in both optical and near-infrared wavelengths. Still, the characteristics of the lines in different wave passbands are not necessarily the same. We searched for lines of Mg I, Si I, Ca I, Ti I, Cr I, and Ni I in the z′, Y, and J bands (0.91–1.33 μm), that are useful for precise abundance analyses, from two different compilations of lines, namely, the third release of Vienna Atomic Line Database (VALD3) and the catalog published by Meléndez & Barbuy in 1999 (MB99). We selected sufficiently strong lines that are not severely blended and ended up with 191 lines (165 and 141 lines from VALD3 and MB99, respectively), in total, for the six elements. Combining our line lists with high-resolution ($\lambda/\Delta\lambda = 28,000$) and high signal-to-noise ratio (> 500) spectra taken with the WINERED spectrograph, we measured the abundances of the six elements in addition to Fe I of two prototype red giants, viz. Arcturus and μ Leo. The resultant abundances show reasonable agreement with the values in the

literature within ~ 0.2 dex, indicating that the available oscillator strengths are acceptable, although the abundances based on the two line lists show systematic differences by 0.1–0.2 dex. Furthermore, to improve the precision, solid estimation of the microturbulence (or the microturbulences if they are different for different elements) is necessary as far as the classical hydrostatic atmosphere models are used for the analysis.

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Transients from ONe white dwarf – neutron star / black hole mergers

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We conduct the first 3D hydrodynamic simulations of oxygen–neon white dwarf – neutron star/black hole mergers (ONe WD–NS/BH mergers). Such mergers constitute a significant fraction, and may even dominate, the inspiral rates of all WD–NS binaries. We post-process our simulations to obtain the nuclear evolution of these systems and couple the results to a supernova spectral synthesis code to obtain the first light curves and spectra for these transients. We find that the amount of ^{56}Ni synthesised in these mergers grows as a strong function of the WD mass, reaching typically 0.05 and up to 0.1 $M_\odot$ per merger. Photodisintegration leads to similar amounts of ^{4}He and about a ten times smaller amount of ^{1}H. The nuclear yields from these mergers, in particular those of ^{55}Mn, may contribute significantly to Galactic chemical evolution. The transients expected from ONe WD–NS mergers are dominantly red/infrared, evolve on month-long timescales and reach bolometric magnitudes of up to -16.5. The current surveys must have already detected these transients or are, alternatively, putting strong constraints on merger scenarios. The properties of the expected transients from WD–NS mergers best agree with faint type Iax supernovæ. The *Vera Rubin* Observatory (LSST) will be detecting up to hundreds of merging ONe WD–NS systems per year. We simulate a subset of our models with 2D axisymmetric FLASH code to investigate why they have been challenging for previous studies. We find that the likely main challenge has been effectively modelling the nuclear statistical equilibrium regime in such mergers.

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Planetary nebulæ in Gaia EDR3: central star identification, properties and binarity

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Context: Gaia Early Data Release 3 (EDR3), published in December 2020, features improved photometry and astrometry over that published in the previous DR2 file, and includes a substantially larger number of sources, of the order of 2,000 million, making it a paradigm of Big data Astronomy. Many of the Central Stars of Planetary Nebulæ

(CSPNe) are inherently faint and difficult to identify within the field of the nebula itself. Gaia measurements may be relevant not only in identifying the ionizing source of each nebula but also in the study their physical and evolutionary properties.
Aims: We demonstrate how Gaia data mining can effectively help to solve the issue of central star misidentification, a problem that has plagued the field since its origin. As we did for DR2, our objective is to present a catalogue of CSPNe with astrometric and photometric information in EDR3. From that catalogue we select a sample of stars with high quality astrometric parameters, on which, we carry out a more accurate analysis of CSPNe properties.
Methods: Gaia G(BP)–G(RP) colours allow us to select the sources with sufficient temperatures to ionize the nebula. In order to estimate the real colour of a source, it is important to take into account interstellar extinction and, in the case of compact nebulæ, nebular extinction when available. In addition, distances derived from EDR3 parallaxes (combined with consistent literature values) can be used to obtain nebular intrinsic properties from those observed. With this information, CSPNe can be plotted in an HR diagram. From information on the spectral classification of the CS (from the literature) and evolutionary models for post-AGB stars, their evolutionary state can then be analysed. Furthermore, EDR3 high quality astrometric data enable us to search for objects comoving with CSs in the field of each nebula by detecting sources with parallaxes and proper motions similar to those of the CS.
Results: We present a catalogue of 2035 PNe with their corresponding CS identification from among Gaia EDR3 sources. We obtain the distances for those with known parallaxes in EDR3 (1725 PNe). In addition, for a subsample (405 PNe) with the most accurate distances, we obtain different nebular properties such as their Galactic distribution, radius, kinematic age and morphology. Furthermore, for a set of 74 CSPNe, we present the evolutionary state (mass and age) derived from their luminosities and effective temperatures from evolutionary models. Finally, we highlight the detection of several wide binary CSPNe through an analysis of the EDR3 astrometric parameters, and we try to shed some light on the relevance of close binarity in CSPNe.

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Semi-regular red giants as distance indicators – I. The period–luminosity relations of semi-regular variables revisited

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Context: Semi-regular variables (SRVs) are similar to Miras in brightness, and they also follow one or more period–luminosity relations (PLRs), though not necessarily the same one as Miras. As potential standard candles they are more challenging than Miras because of their smaller variability amplitudes and less regular light curves, but they are substantially more numerous and especially promising for probing old stellar populations.
Aims: We aim to characterise the variability of SRVs, specifically focusing on their connection with Miras, in order to prepare the ground for investigating their potential as distance indicators.
Methods: We examine SRVs and Miras in the Magellanic Clouds from OGLE-III observations, with data from Gaia and 2MASS. After cleaning the sample of variability periods unrelated to pulsation, we classify each source by chemical type and combination of pulsation modes. We examine the results in terms of global photometric and pulsation properties.
Results: We identify four SRV groups that fit the general evolutionary scenario predicted by theory. SRVs dominated by fundamental mode pulsation are very similar to Miras, especially if mono-periodic. They further split into two subgroups, one of which follows the same sequence as Miras in the period–luminosity and period–amplitude diagrams, without discontinuity.
Conclusions: The similarities between Miras and SRVs suggest that the latter can be adopted as distance indicators in a way that is complementary to the use of the former, thereby at least doubling the available number of long-period variables (LPVs) suitable for use as distance indicators. The traditional amplitude-based separation between Miras and SRVs is not necessarily appropriate, and a more physically sound criterion should also involve pulsation periods. While this would require comparatively longer time-series, they are expected to become accessible in the coming years

even for weak sources thanks to current and future large-scale surveys. The table of reclassified LPVs is made public.

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Variability in proto-planetary nebulæ – VIII. A new sample of southern hemisphere objects

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As part of our continuing study of light variability in proto-planetary nebulæ (PPNe), we present the results from a long-term study of nine southern hemisphere objects. We have monitored their light variations over a nine-year interval from 2010–2018. These were supplemented by data from the ASAS-SN and ASAS-3 surveys, leading to combined light curves from 2000 to 2020. Pulsation periods were found in seven of the objects, although the three shortest must be regarded as tentative. The periods range from 24 to 73 days. When compared with the results of previous studies of the light variations in PPNe, we find that they show the same trends of shorter period and smaller light variations with higher temperatures. Luminosities were calculated based on the spectral energy distributions, reddening, and Gaia distances, and these confirm the identification of all but one as post-AGB objects. Three of the stars possess long-period variations of 5 to 19 years. These are most likely due to the periodic obscuration of the star by a disk, suggesting the presence of a binary companion and a circumbinary disk.

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Velocity segregation in a clump-like outflow with a non-top hat velocity cross-section

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High velocity clumps joined to the outflow source by emission with a "Hubble law" ramp of linearly increasing radial velocity vs. distance are observed in some planetary nebulae and in some outflows in star formation regions. We propose a simple model in which a "clump" is ejected from a source over a period τ_0, with a strong axis to edge velocity stratification. This non-top hat cross section results in the production of a highly curved working surface (initially being pushed by the ejected material, and later coasting along due to its inertia). From both analytic models and numerical simulations we find that this working surface has a linear velocity vs. position ramp, and therefore reproduces in a qualitative way the "Hubble law clumps" in planetary nebulæ and outflows from young stars.

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Two-wind interactions in binaries with two orbiting giant stars

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Some red giant envelopes present spiral structures (seen either in dust-scattered stellar continuum or in molecular line emission), the most striking example probably being AFGL 3068. This object has been modeled (both analytically and numerically) in terms of a wind ejected from a star in orbit around a binary companion. We revisit both analytical models and 3D simulations of a wind from an orbiting red giant star, and extend the numerical simulations to the case of a binary with two red giants with strong winds. We find that most two-wind models on the orbital plane show a "double spiral" structure close to the binary source, and that these two arms merge into a single spiral structure at larger distances. However, for the case of a binary with two identical winds, the two spiral arms are still present at large distances from the binary source. We also find that for models of two (not identical) dynamically important winds, a region close to the orbital plane has material from both winds. Also, an approximately conical region centered on the orbital axis is filled exclusively by the wind with larger momentum rate. These two structures lead to morphologies reminiscent of the so-called "hour glass" planetary nebulæ. Finally, we find that increasing wind velocity disparities lead to the formation of clumpy structures along the spiral arms. Observations of "clumpy spirals" are therefore likely to indicate the presence of two strong winds from the stars in the central binary system.

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Job Adverts

European Southern Observatory ESO fellowship program

Dear colleagues,

ESO invite applications for the ESO Fellowship Programme 2021/2022 in Chile and Germany. The Programme is designed to help young scientists to develop their independent research programmes and successfully reach the next step of their scientific careers. The deadline to apply is 15 October 2021. Details at
http://eso.org/sci/activities/fellowships-and-studentships/FeSt-overview/fellowship_programme.html

Best Regards
Claudia Paladini

See also https://recruitment.eso.org

Two postdoctoral contracts at the Instituto de Astrofísica de Canarias (IAC)

The IAC (Tenerife) announces TWO postdoctoral contracts to work on topics within the projects NanoFull (PROID2020010051) financed by the ACIISI with funds from the Operational Program FEDER Canarias and

COSJWST (PID2020-115758GB-I00) financed by MICINN, led by Dr. Domingo Aníbal García-Hernández.

Research topics at the IAC include most areas of astrophysics: Solar Physics (FS), Exoplanetary System and Solar System (SEYSS), Stellar and Interstellar Physics (FEEI), The Milky Way and The Local Group (MWLG), Formation and Evolution of Galaxies (FYEG), and Cosmology and Astroparticles (CYA–CTA). All of these are supported by an ambitious instrumentation programme. In 2020, the IAC was granted by the Spanish Government the status of Severo Ochoa Center of Excellence, a prestigious recognition awarded for the third time to the IAC as a leading research institute in Spain. Further information about the IAC's research programme, its Observatories and the 10.4m GTC is available at the IAC's web page: https://www.iac.es/.

Postdoc 1: "Multi-wavelength astronomical observations of complex organic species"

Tasks: The successful candidate will pursue research in one or more of the following fields:

- Analysis of multi-wavelength spectroscopic observations (from the UV to the far-IR) of fullerene-rich circumstellar envelopes.
- Comparison of laboratory and/or theoretical spectra with astronomical observations.
- Scientific exploitation of the data provided by the *James Webb* telescope and preparation for data collection in cycle 2.
- Preparation for obtaining (and subsequent analysis) of additional data on circumstellar envelopes in the IR and radio wavelength ranges.

Particular attention will be given to applicants with experience in the field of multi-wavelength spectroscopic data (from the UV to the far-IR) with space telescopes.

Complete information about this postdoc position can be found here:
https://www.iac.es/en/employment/one-postdoctoral-contract-nanofull-cosjwst-2021-ps-2021-081

Postdoc 2: "Quantum chemistry simulations of complex organic species"

Tasks: The successful candidate will pursue research in the following fields:

- Computational quantum-chemical simulations of complex organic species (fullerene and graphene compounds as well as large aromatic/aliphatic species).
- Identification of the nature of the vibrational modes seen in the laboratory/astronomical data.
- Exploration of the footprints of fullerene/graphene derivatives and larger molecules in the radio wavelength range.

Particular attention will be given to applicants with experience and good knowledge in the fields of quantum mechanics and chemistry, group theory and spectroscopy, and electronic structure theory (especially when applied to fullerene/graphene derivatives and/or other large organic species).

Complete information about this postdoc position can be found here:
https://www.iac.es/en/employment/one-postdoctoral-contract-cosjwst-quimica-cuantica-2021-ps-2021-080

The application deadline for both postdoc positions is November 15, 2021.

For inquiries about the jobs please contact Dr. Domingo Aníbal García Hernández (agarcia@iac.es).

See also https://www.iac.es/en/employment/one-postdoctoral-contract-nanofull-cosjwst-2021-ps-2021-081
and https://www.iac.es/en/employment/one-postdoctoral-contract-cosjwst-quimica-cuantica-2021-ps-2021-080

Announcements

workshop "Evolved Stars and their Circumstellar Environments" Dec 14–17

The SOFIA Science Center is pleased to announce the upcoming online workshop "Evolved Stars and their Circumstellar Environments", happening on December 14–17, 2021. The event – see abstract below – will be an exciting platform for discussions about the current main questions in the field of evolved stars, and the next observational opportunities. Several invited speakers have already confirmed attendance, and we strongly encourage you to submit an abstract for a contributed talk – before November 22nd.

There is no registration deadline or fee, and we strongly support participation from all interested scientists, in particular early-career.

Abstract:
When low- and intermediate-mass stars exhaust their nuclear fuel in their cores, they expand and enter the giant branch in the HR diagram. Eventually, some also ascend the asymptotic giant branch (AGB), potentially leading to planetary nebulæ formation. AGB stars dominate the enrichment of several of the pre-biotic elements (e.g., C, N) and are therefore critical to our understanding of Galactic chemical evolution. The evolution of supergiants can provide information on open cluster evolution and star formation history. Generally speaking, evolved stellar objects also provide unique laboratories for the study of molecule and dust formation and matter-radiation interactions in highly irradiated environments.

This workshop will explore how theoretical and observational studies of evolved stellar objects can contribute to the understanding of a critical part of stellar evolution. Because giant stars tend to be cool with significant circumstellar, often dusty, envelopes, red [super] giants, AGB stars, planetary nebulæ, and related objects are ideally suited for studies at infrared and [sub]mm wavelengths. We will encourage discussions on synergies between infrared observations and other techniques, and how laboratory work can contribute to the advancement of the field.

Addressed topics will include:

- Gas chemistry in different regions of stellar objects / different star types
- Connection to the ISM
- Elemental enrichment
- Dust formation theory
- Dust observations: chemical composition and polarimetric properties
- Temporal evolution
- Related Laboratory Experimental studies

See also https://sofia-science-series.constantcontactsites.com/

IAU Ph.D. Prize

The Organizing Committee of the IAU H3 Inter-Division G–H Commission Planetary Nebulæ would like to encourage the application of candidates that defended their thesis in the PNe field to the IAU Ph.D. Prize:

The IAU Ph.D. Prize recognises outstanding scientific achievement in astrophysics around the world. Each IAU Division has, once a year, the opportunity to award its own prize to the candidate it feels has carried out the most remarkable work in the previous year (i.e. a Ph.D. Thesis which has been defended between the 16 December in the previous year, and 15 December this year). Theses which are in preparation or submitted, but not yet defended by the deadline of a given year will have to be submitted the following year.

The recipient of each award receives a range of prizes, tailored by each Division at their own discretion. A standard prize includes airfare and accommodation to attend the next IAU General Assembly where certificates will be awarded. Other prizes might include the opportunity to present their thesis work at Division Days, an invitation to attend presentations to the IAU Executive Committee meeting and dinner at the General Assembly, and the possibility of presenting a talk at either a plenary or special session.

Candidates are required to submit: an abstract of their thesis that is suitable for public consumption; a 1500-word thesis summary; three letters of recommendation (including one from the Ph.D. advisor); and a CV. The winner of each Division will be decided by the Division's own standards and methods – guided by the Division Steering Committee – and possibly with corroborating external consultation or additional letters of recommendation.

The IAU Ph.D. Prize is open to candidates from any country, regardless of whether the country has an IAU National Membership. On top of this, a separate prize is available to be awarded to applicants from developing countries (defined as those not in the OECD).

The deadline for all applications is 15 December every year, to include all applications since the previous year's deadline. The application form is available here: https://www.iau.org/submissions/phd-prize/

Please note that the deadline is at 11:59 PM in the IAU office in Paris, France (GMT+1).

More information:
https://www.iau.org/science/grants_prizes/phd_prize/
https://www.iau.org/science/scientific_bodies/commissions/H3/