THE AGB NEWSLETTER

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Editors: Jacco van Loon, Ambra Nanni and Albert Zijlstra

Editorial

Dear Colleagues,

Happy New Year! It is our pleasure to present you the 294$^{\rm th}$ issue of the AGB Newsletter. Ideas for the celebratory 300$^{\rm th}$ issue (July) are welcome. Besides scientific contributions think also of art, philosophy or human perspectives.

Note the imminent deadline for applications for a fellowship in Spain. There's a little more time to apply for one in South Korea – note also their commitment to mitigate against personal bias by anonymising much of the application.

Please see the announcement on behalf of the AAVSO at the end of the newsletter – as many already know this organisation has made tremendous contributions to our knowledge of the variable skies through its amateur–professional partnerships and databases. The data often date back many decades and many amateurs have excellent equipment. Did you know they also monitor spectroscopically? They are very keen for dialogue to guide the most interesting work. Reactions are welcome and will be discussed in a subsequent edition.

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

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

Food for Thought

This month's thought-provoking statement is:

The main uncertainty in predicting the outcome of binary interaction is the internal redistribution of angular momentum.

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

Simulating the outcome of binary neutron star merger in common envelope jets supernovæ

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We simulate the influence of the energy that the merger process of two neutron stars (NSs) releases inside a red supergiant (RSG) star on the RSG envelope inner to the merger location. In the triple star common envelope evolution (CEE) that we consider a tight binary system of two NSs spirals-in inside an RSG envelope and because of mass accretion and dynamical friction the two NS merge. We deposit merger-explosion energies of 3×10^{50} and 1×10^{51} erg at distances of 25 $R_\odot$ and 50 $R_\odot$ from the center of the RSG, and with the three-dimensional hydrodynamical code FLASH we follow the evolution of the RSG envelope in inner regions. For the parameters we explore we find that more than 90 per cent of the RSG envelope mass inner to the merger site stays bound to the RSG. NSs that experience a CEE are likely to accrete RSG envelope mass through an accretion disk that launches jets. These jets power a luminous transient event, a common envelope jets supernova (CEJSN). The merger process adds to the CEJSN energy. Our finding implies that the interaction of the merger product, a massive NS or a BH, with the envelope can continue to release more energy, both by further in-spiral and by mass accretion by the merger product. Massive RSG envelopes can force the merger product to spiral-in into the core of the RSG, leading to an even more energetic CEJSN.

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Seismic signature of electron degeneracy in the core of red giants: hints for mass transfer between close red-giant companions

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The detection of mixed modes in red giants with space missions CoRoT and *Kepler* has revealed their deep internal structure. These modes allow us to characterize the pattern of pressure modes (through the measurement of their asymptotic frequency separation $\Delta\nu$) and the pattern of gravity modes (through the determination of their asymptotic period spacing $\Delta\Pi_1$). It has been shown that red giant branch (RGB) stars regroup on a well-defined sequence in the $\Delta\nu$–$\Delta\Pi_1$ plane. Our first goal is to theoretically explain the features of this sequence and understand how it can be used to probe the interiors of red giants. Using a grid of red giant models computed with MESA, we demonstrate that red giants join the $\Delta\nu$–$\Delta\Pi_1$ sequence whenever electron degeneracy becomes strong in the core. We argue that this can be used to estimate the central densities of these stars, and potentially to measure the amount of core overshooting during the main sequence part of the evolution. We also investigate a puzzling subsample of red giants that are located below the RGB sequence, in contradiction with stellar evolution models. After checking the measurements of the asymptotic period spacing for these stars, we show that they are mainly intermediate-mass red giants. This is doubly peculiar because these stars should have nondegenerate cores and are expected to be located well above the RGB sequence. We show that these peculiarities are well accounted for if these stars result from the interaction between two low-mass ($M \lesssim 2$ $M_\odot$) close companions during the red giant branch phase. If the secondary component has already developed a degenerate core before mass transfer begins, it becomes an intermediate-mass giant with a degenerate core. The secondary star is then located below the degenerate sequence, which is in agreement with the observations.

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Available from https://arxiv.org/abs/2108.11848

A binary with a δ Scuti star and an oscillating red giant: orbit and asteroseismology of KIC 9773821

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We study the δ Scuti – red giant binary KIC 9773821, the first double-pulsator binary of its kind. It was observed by *Kepler* during its four-year mission. Our aims are to ascertain whether the system is bound, rather than a chance alignment, and to identify the evolutionary state of the red giant via asteroseismology. An extension of these aims is to determine a dynamical mass and an age prior for a δ Sct star, which may permit mode identification via further asteroseismic modelling. We determine spectroscopic parameters and radial velocities (RVs) for the red giant component using HERMES@Mercator spectroscopy. Light arrival-time delays from the δ Sct pulsations are used with the red-giant RVs to determine that the system is bound and to infer its orbital parameters, including the binary mass ratio. We use asteroseismology to model the individual frequencies of the red giant to give a mass of $2.10^{+0.20}_{-0.10}$ $M_\odot$ and an age of $1.08^{+0.06}_{-0.24}$ Gyr. We find that it is a helium-burning secondary clump star, confirm that it follows the standard $\nu_{\rm max}$ scaling relation, and confirm its observed period spacings match their theoretical counterparts in the modelling code MESA. Our results also constrain the mass and age of the δ Sct star. We leverage these constraints to construct δ Sct models in a reduced parameter space and identify four of its five pulsation modes.

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Spectral characterisation of inertial particle clustering in turbulence

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Clustering of inertial particles is important for many types of astrophysical and geophysical turbulence, but it has been studied predominately for incompressible flows. Here we study compressible flows and compare clustering in both compressively (irrotationally) and vortically (solenoidally) forced turbulence. Vortically and compressively forced flows are driven stochastically either by solenoidal waves or by circular expansion waves, respectively. For compressively forced flows, the power spectrum of the density of inertial particles is a useful tool for displaying particle clustering relative to the fluid density enhancement. Power spectra are shown to be particularly sensitive for studying large-scale particle clustering, while conventional tools such as radial distribution functions are more suitable for studying small-scale clustering. Our primary finding is that particle clustering through shock interaction is particularly prominent in turbulence driven by spherical expansion waves. It manifests itself through a double-peaked distribution of spectral power as a function of Stokes number. The two peaks are associated with two distinct clustering mechanisms; shock interaction for smaller Stokes numbers and the centrifugal sling effect for larger values. The clustering of inertial particles is associated with the formation of caustics. Such caustics can only be captured in the Lagrangian description, which allows us to assess the relative importance of caustics in vortically and compressively forced turbulence. We show that the statistical noise resulting from the limited number of particles in the Lagrangian description can be removed from the particle power spectra, allowing us a more detailed comparison of the residual spectra. We focus on the Epstein drag law relevant for rarefied gases, but show that our findings apply also to the usual Stokes drag.

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The extended atmosphere and circumstellar environment of the cool evolved star VX Sagittarii as seen by MATISSE

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Context: VX Sgr is a cool, evolved, and luminous red star whose stellar parameters are difficult to determine, which affects its classification. Aims. We aim to spatially resolve the photospheric extent as well as the circumstellar environment.

Methods: We used interferometric observations obtained with the MATISSE instrument in the L (3–4 μm), M (4.5–5 μm), and N (8–13 μm) bands. We reconstructed monochromatic images using the MIRA software. We used 3D radiation-hydrodynamics (RHD) simulations carried out with CO5BOLD and a uniform disc model to estimate the apparent diameter and interpret the stellar surface structures. Moreover, we employed the radiative transfer codes OPTIM3D and RADMC3D to compute the spectral energy distribution for the L, M, and N bands, respectively.

Results: MATISSE observations unveil, for the first time, the morphology of VX Sgr across the L, M, and N bands. The reconstructed images show a complex morphology with brighter areas whose characteristics depend on the wavelength probed. We measured the angular diameter as a function of the wavelength and showed that the photospheric extent in the L and M bands depends on the opacity through the atmosphere. In addition to this, we also concluded that the observed photospheric inhomogeneities can be interpreted as convection-related surface structures. The comparison in the N band yielded a qualitative agreement between the N-band spectrum and simple dust radiative transfer simulations. However, it is not possible to firmly conclude on the interpretation of the current data because of the difficulty in constraing the model parameters using the limited accuracy of our absolute flux calibration.

Conclusions: MATISSE observations and the derived reconstructed images unveil the appearance of VX Sgr's stellar surface and circumstellar environment across a very large spectral domain for the first time.

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3D spatio-kinematic modeling of Abell 48, a planetary nebula around a Wolf–Rayet [WN] star

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The planetary nebula (PN) Abell 48 (PN G029.0+00.4) is around a rare Wolf–Rayet [WN5] star whose stellar history is as yet unknown. Using the integral field observations of the Hα λ6563 and [N II] λ6584 line emissions, we conducted a comprehensive spatio-kinematic analysis of this PN. A three-dimensional spatio-kinematic ionization model was developed with the kinematic modeling tool SHAPE to replicate the observed spatially-resolved velocity channels and position–velocity diagrams. According to our kinematic analysis of the Hα emission, this object possesses a deformed elliptic toroidal shell with an outer radius of 23″ and a thickness of 15″ associated with an integrated Hα emission-line expansion of $\sim 35 \pm 5$ km s^{-1}, a maximum poloidal expansion of around 70 ± 20 km s^{-1} at an inclination angle of $\sim 30°$ with respect to the line of sight, and a position angle of $\sim 130°$ measured from East toward North in the equatorial coordinate system. Furthermore, [N II] kinematic modeling reveals the presence of narrow ($\sim 3''$) exterior low-ionization structures surrounding the main elliptical shell, which could have formed as a result of shock collisions

with the interstellar medium. The torus-shaped morphology of this PN could be related to its unusual hydrogen-deficient [WN] nucleus that needs to be inspected further.

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An episodically variable stellar wind in the planetary nebula IC 4997

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IC 4997 is a planetary nebula well known by its variability. We present high-resolution spectra of IC 4997 obtained in 1993, 2019, and 2020 that reveal changes in the Hα and [N II] emission line profiles, which had never been reported for this object. The Hα P Cygni emission profile observed in 1993 changed to a single-peaked profile in 2019–2020, implying that the stellar wind has largely weakened. The very broad Hα emission wings narrowed by a factor of $\sim$ 2 between 1993 and 2019–2020, indicating that the efficiency of the Rayleigh–Raman scattering has noticeably decreased. A high-velocity [N II] nebular component detected in 1993 is missing in 2019 and 2020, probably due to a decrease in its electron density. A correlation exists between the strength of the stellar wind and the episodic ($\sim$ 50–60 yr) variation in the [O III]λ4363/Hγ line intensity ratio, suggesting that an episodic, smoothly variable stellar wind is the main cause of the variability of IC 4997. Monitoring of that intensity ratio and of the Hα emission line profile in the coming years and new multiwavelength observations are key to unveiling the ongoing processes in IC 4997 and constraining the origin of the wind variability.

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Optical and near-infrared spectroscopy of Nova V2891 Cygni: evidence for shock-induced dust formation

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We present multi-epoch optical and near-infrared observations of the highly reddened, Fe II-class slow nova V2891 Cygni. The observations span 15 months since its discovery. The initial rapid brightening from quiescence, and the presence of a $\sim$ 35-day long pre-maximum halt, is well documented. The evidence that the current outburst of V2891 Cyg has undergone several distinct episodes of mass ejection is seen through time-varying P-Cygni profiles of the O I 7773Å line. A highlight is the occurrence of a dust formation event centred around $\sim$ +273 d, which coincides with a phase of coronal line emission. The dust mass is found to be ~ 0.83–1.25×10^{-10} $M_{\odot}$. There is strong evidence to suggest that the coronal lines are created by shock heating rather than by photoionization. The simultaneous occurrence of

the dust and coronal lines (with varying velocity shifts) supports the possibility that dust formation is shock-induced. Such a route for dust formation has not previously been seen in a nova, although the mechanism has been proposed for dust formation in some core-collapse supernovæ. Analysis of the coronal lines indicates a gas mass and temperature of 8.35–8.42 $\times 10^{-7}$ $M_\odot$ and $\sim$ (4.8–9.1) $\times 10^5$ K respectively, and an overabundance of aluminium and silicon. A Case B analysis of the hydrogen lines yields a mass of the ionized gas of $(8.60 \pm 1.73) \times 10^{-5}$ $M_\odot$. The reddening and distance to the nova are estimated to be $E(B-V) = 2.21 \pm 0.15$ and $d = 5.50$ kpc respectively.

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Near-infrared studies of nova V1674 Herculis: a shocking record-breaker

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We present near infrared spectroscopy of Nova Herculis 2021 (V1674 Her), obtained over the first 70 days of its evolution. This fastest nova on record displays a rich emission line spectrum, including strong coronal line emission with complex structures. The hydrogen line fluxes, combined with a distance of $4.7^{+1.3}_{-1.0}$ kpc, give an upper limit to the hydrogen ejected mass of $M_{\rm ej} = 1.4^{+0.8}_{-1.2} \times 10^{-3}$ $M_\odot$. The coronal lines appeared at day 11.5, the earliest onset yet observed for any classical nova, before there was an obvious source of ionizing radiation. We argue that the gas cannot be photoionized, at least in the earliest phase, and must be shocked. Its temperature is estimated to be $10^{5.57\pm0.05}$ K on day 11.5. Tentative analysis indicates a solar abundance of aluminum and an underabundance of calcium, relative to silicon, with respect to solar values in the ejecta. Further, we show that the vexing problem of whether collisional or photoionization is responsible for coronal emission in classical novæ can be resolved by correlating the temporal sequence in which the X-ray supersoft phase and the near-infrared coronal line emission appear.

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Eclipsing white dwarf binaries in Gaia and the Zwicky Transient Facility

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Gaia provided the largest-ever catalogue of white dwarf stars. We use this catalogue, along with the third public data release of the Zwicky Transient Facility (ZTF), to identify new eclipsing white dwarf binaries. Our method exploits light curve statistics and the Box Least Squares algorithm to detect periodic light curve variability. The search revealed 18 new binaries, of which 17 are eclipsing. We use the position in the Gaia H–R diagram to classify these binaries and find that the majority of these white dwarfs have main sequence companions. We identify one system as a candidate eclipsing white dwarf–brown dwarf binary and a further two as extremely low mass (ELM) white dwarf binaries. We also provide identification spectroscopy for 17 of our 18 binaries. Running our search method on mock light curves with real ZTF sampling, we estimate our efficiency of detecting objects with light curves similar to the ones of the

newly discovered binaries. Many more binaries are to be found in the ZTF footprint as the data releases grow, so our survey is ongoing.

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Optical and NIR spectroscopy of cool CEMP stars to probe the nucleosynthesis in low-mass AGB binary system

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We present the abundance analyses of seven carbon enhanced metal-poor (CEMP) stars to understand the origin of carbon in them. We used high-resolution optical spectra to derive abundances of various elements. We also used low-resolution nearinfrared (NIR) spectra to derive the abundance of O and $^{12}C/^{13}C$ from the CO molecular band and compared their values with those derived from high-resolution optical spectra. We identified a good agreement between the values. Thus, in cool CEMP stars, the NIR observations complement the high-resolution optical observations to derive the oxygen abundance and the $^{12}C/^{13}C$ ratio. This enables us to probe fainter cool CEMP stars using NIR spectroscopy. C, N, O abundances of all the program stars in this study show abundances that are consistent with binary mass transfer from a low-mass, low-metallicity asymptotic giant branch (AGB) companion which is further supported by the presence of enhancement in neutron-capture elements and detection of radial velocity variation. One of the stars shows abundance patterns similar to a CEMP-s star whereas the abundance pattern of the rest of the stars satisfy the criteria required to classify them as CEMP-r/s stars. The subclassification of some of the stars studied here is revisited. The abundance of neutron-capture elements in these CEMP-r/s stars resembles to that of i-process models where proton ingestion episodes in the companion low-mass, low metallicity AGB stars produce the necessary neutron density required for the onset of i-process.

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The frequency by mass of Galactic carbon stars inferred from Gaia measurements of star cluster members

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We investigate the frequency of occurrence of Galactic carbon stars as a function of progenitor mass using Gaia data. Small number statistics limit fidelity, but C-star frequency agrees with that observed in the Magellanic Clouds (MCs) down to $m \approx 1.67$ $M_\odot$. At $m \approx 1.38$ $M_\odot$, the frequency rises by a factor of three even though the frequency appears to drop to zero for the MCs. In fact this is due to a lack of clusters at the key age range in the MCs. At $m \approx 1.24$ $M_\odot$ and below, no C-stars are observed, corresponding to ages older than 4 Gyr. Within uncertainties, C-star frequency in M 31 is consistent with that of the Galaxy and the MCs. We find an ambiguous C-star candidate at ~ 7 $M_\odot$.

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A census of thermally-pulsing AGB stars in the Andromeda galaxy and a first estimate of their contribution to the global dust budget

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We present a near-complete catalog of the metal-rich population of Thermally-Pulsing Asymptotic Giant Branch stars in the northwest quadrant of M 31. This metal-rich sample complements the equally complete metal-poor Magellanic Cloud AGB catalogs produced by the SAGE program. Our catalog includes HST wide-band photometry from the Panchromatic *Hubble* Andromeda Treasury survey, HST medium-band photometry used to chemically classify a subset of the sample, and *Spitzer* mid- and far-IR photometry that we have used to isolate dust-producing AGB stars. We have detected 346,623 AGB stars; these include 4,802 AGB candidates producing considerable dust, and 1,356 AGB candidates that lie within clusters with measured ages, and in some cases metallicities. Using the *Spitzer* data and chemical classifications made with the medium-band data, we have identified both carbon- and oxygen-rich AGB candidates producing significant dust. We have applied color–mass-loss relations based on dusty AGB stars from the LMC to estimate the dust injection by AGB stars in the PHAT footprint. Applying our color relations to a subset of the chemically-classified stars producing the bulk of the dust, we find that $\sim 97.8\%$ of the dust is oxygen-rich. Using several scenarios for the dust lifetime, we have estimated the contribution of AGB stars to the global dust budget of M 31 to be 0.9–35.5%, which is in line with previous estimates in the Magellanic Clouds. Follow-up observations of the M 31 AGB candidates with the JWST will allow us to further constrain stellar and chemical evolutionary models, and the feedback and dust production of metal-rich evolved stars.

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Review Paper

Will Betelgeuse explode?

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Since October 2019, Betelgeuse began to dim noticeably and by January 2020 its brightness had dropped by a factor of approximately 2.5, demoting it from the position of the top (apparent) brightest 11^{th} star to the 21^{st}! Astronomers were excited and thought of it as the lull before the storm, Betelgeuse was ready to go supernova!
This article is aimed more as a case study where we show how this question was answered using scientific arguments and data. It will also highlight the importance of supernovae to human existence and give a brief discussion on the evolution of massive stars. And also, answer the question!

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Available from https://arxiv.org/abs/2105.09791

Job Adverts

University of Alicante (Spain) Short-term postdoctoral position

The University of Alicante Stellar Astrophysics Group (https://astro.ua.es/en/) is offering a short-term senior postdoctoral position at the Department of Applied Physics of the University of Alicante (https://dfapl.ua.es/en/news.html) to participate in research activities corresponding to our current grant "An observational landscape for supernova and gravitational wave event progenitors" (PGC2018-093741-B-C21). The contract will last from the earliest possible starting date until the end of the grant (September 30^{th}, 2022). The gross salary is 2400 euro/month. This is a good opportunity for anyone who needs a bridge between two contracts.

The researcher will have to carry out tasks related to (some of) the main research lines in our group:

- Preparation and analysis of our contribution to the WEAVE/SCIP spectroscopic survey (mostly related to red supergiants);
- Properties of red supergiants;
- Study of young open clusters and OB associations;
- Spectroscopic analysis of massive stars in different kinds of binary systems;
- Study of star forming regions that contain massive stars (also obscured regions);
- Characterisation of massive X-ray binaries,

and any other related tasks that may naturally emerge. Applications are open between December 27^{th} and January 11^{th}. Applicants must have received a Ph.D. by the application deadline (January 11^{th}, 2022). Any successful non-EU applicant must obtain a residence and work permit from the Spanish immigration authorities (the University may help with the process). We will value previous experience with massive stars and/or spectroscopic analysis.

Further details are provided by the university only in Spanish or Catalan at the url below. Please contact me (ignacio.negueruela@ua.es) for further information.

See also https://ssyf.ua.es/es/accesopdi/personal-investigador/2021/11921/personal-investigador-i-pi-119-21.html

Korea Astronomy and Space Science Institute – Postdoc fellow

The Korea Astronomy and Space Science Institute invites applications to a postdoc fellow to work on evolved stars. The successful candidate is expected to lead a creative research program that establishes new collaborations between the institute's research topics. The application deadline is Feb 4^{th} 2022, 3:00 p.m. KST.

Recommended Research Topics:

- Hydrodynamical simulations for symbiotic stars.
- ALMA observational data analyses for the spatio-kinematical structures of circumstellar envelopes of evolved stars.
- Development of analysis methods.

Knowledge & Skills Required:

- More than one experiment among hydrodynamical simulations, molecular line observations with interferometry, and radiative transfer calculations.
- Background knowledge on evolved stars.
- Skills on astronomical data analysis, image processing, and statistics.

Attitude:

- Clear self-motivation for the job to be performed.
- Concentration, patience, and responsibility for problem solving.
- Attitude required for collaborations.

Basic Ability:

- Good English communication, logical thinking, and interpersonal relations.

Requirements for candidates:

- New hires may be appointed as postdocs only if their starting date is within 5 years of receiving their Ph.D. (including those who are going to obtain their Ph.D. before the appointment date).
- To proceed with a fair recruitment process, the personally identifiable information which is unrelated to one's work such as name (first name and surname), picture, names of educational institutions, gender, sexual orientation, address, family or relatives cannot be mentioned in the CV, Research plan, or other necessary documents.

For more information, see P5 in https://www.kasi.re.kr/eng/recruit/post/recruitNotice/28973
Inquiries: Hyosun Kim, hkim@kasi.re.kr
Apply online at https://www.kasi.re.kr/eng/post/eng_jobopening

Announcement

The AAVSO is Here to Help

The AAVSO and its team of highly skilled and dedicated amateur astronomers are here to support your research.

We welcome any opportunity to launch an observing campaign to provide optical band photometry to coincide with your observations at non-optical wavelengths. Just let us know what your observing requirements are and we'll match you with the right observers.

We have observers who can provide high precision J- and K-band photoelectric photometry of bright stars like Betelgeuse.

We have observers who can provide low to high resolution spectroscopy. We are training more and more observers each year on this technique and these observers are looking for high value targets.

And of course, the AAVSO maintains an expansive database of visual observations. Many AGB stars in the database have a century worth of data available to monitor for long term changes in behavior.

I'm the AAVSO's section leader for AGB stars so please feel free to reach out to me to see how we can support your efforts.

Richard.w.roberts74@gmail.com

See also https://www.aavso.org