THE AGB NEWSLETTER

An electronic publication dedicated to Asymptotic Giant Branch stars and related phenomena

Official publication of the IAU Working Group on Red Giants and Supergiants

No. 263 — 1 June 2019

http://www.astro.keele.ac.uk/AGBnews

Editors: Jacco van Loon, Ambra Nanni and Albert Zijlstra

Editorial

Dear Colleagues,

It is a pleasure to present you the 263$^{\rm rd}$ issue of the AGB Newsletter.

Don't ignore the White Papers that are being prepared for the USA Decadal survey. They offer reviews and research directions – if anyone would like to comment on any of them then feel free to write to us and we'd be happy to address your responses in the newsletter editorial.

If you like lithium, there's a conference for you (n Rome). If you like common envelopes, then there's a meeting for you too (in London).

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

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

Food for Thought

This month's thought-provoking statement is:

What is the most critical element for AGB evolution after hydrogen and helium?

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

Colours of the flickering source of Mira

R. Zamanov[1], S. Boeva[1], B. Spassov[1], G. Latev[1], U. Wolter[2] and K.A. Stoyanov[1]

[1]Institute of Astronomy and NAO, Bulgarian Academy of Sciences, Sofia, Bulgaria
[2]Hamburger Sternwarte, Universität Hamburg, Hamburg, Germany

We report photometric observations in Johnson UBV bands of the short term variability of Mira. The amplitude detected is 0.16 mag in B band. Adopting interstellar extinction $E(B-V)=0$, we find for the flickering source colour $B-V=1.3$ mag, temperature $T=3400$ K, and radius $R=0.77$ $R_{\odot}$. The colour of the flickering source of Mira B is considerably redder than the average B–V colour of cataclysmic variables and of the symbiotic Mira EF Aql.
(acknowledgement: project KP-06-H28/2 08.12.2018)

Accepted for publication in Bulgarian Astron. J. (BlgAJ)
Available from https://arxiv.org/abs/1903.03782

Confronting expansion distances of planetary nebulæ with Gaia DR2 measurements

Detlef Schönberner[1] and Matthias Steffen[1]

[1]Leibniz-Institut für Astrophysik Potsdam, AIP

Individual distances to planetary nebulæ are of the utmost relevance for our understanding of post-asymptotic giant-branch evolution because they allow a precise determination of stellar and nebular properties. Also, objects with individual distances serve as calibrators for the so-called statistical distances based on secondary nebular properties. With independently known distances, it is possible to check empirically our understanding of the formation and evolution of planetary nebulæ as suggested by existing hydrodynamical simulations.
We compared the expansion parallaxes that have recently been determined for a number of planetary nebulæ with the trigonometric parallaxes provided by the Gaia Data Release 2.
Except for two out of 11 nebulæ, we found good agreement between the expansion and the Gaia trigonometric parallaxes without any systematic trend with distance. Therefore, the Gaia measurements also prove that the correction factors necessary to convert proper motions of shocks into Doppler velocities cannot be ignored. Rather, the size of these correction factors and their evolution with time as predicted by 1-D hydrodynamical models of planetary nebulæ is basically validated. These correction factors are generally greater than unity and are different for the outer shell and the inner bright rim of a planetary nebula. The Gaia measurements also confirm earlier findings that spectroscopic methods often lead to an overestimation of the distance. They also show that even modeling of the entire system of star and nebula by means of sophisticated photo-ionization modeling may not always provide reliable results.
The Gaia measurements confirm the basic correctness of the present radiation-hydrodynamics models, which predict that both the shell and the rim of a planetary nebula are two independently expanding entities, created and driven by different physical processes, namely thermal pressure (shell) or wind interaction (rim), both of which vary differently with time.

Accepted for publication in A&A
Available from https://arxiv.org/abs/1904.10721

Observation of narrow polar jets in the nascent wind of oxygen-rich AGB star EP Aqr

P. Tuan-Anh[1], *D.T. Hoai*[1,2], *P.T. Nhung*[1], *P. Darriulat*[1], *P.N. Diep*[1,2], *T. Le Bertre*[3], *N.T. Phuong*[1,2], *T.T. Thai*[1] *and J.M. Winters*[4]

[1]Department of Astrophysics, Vietnam National Space Center(VNSC), Vietnam Academy of Science and Technology (VAST), 18 Hoang Quoc Viet, Cau Giay, Ha Noi, Viet Nam

[2]Graduate University of Science and Technology (GUST), Vietnam Academy of Science and Technology (VAST), 18 Hoang Quoc Viet, Cau Giay, Ha Noi, Viet Nam

[3]LERMA, UMR 8112, CNRS and Observatoire de Paris, PSL Research University, 61 av. de l'Observatoire, F-75014 Paris, France

[4]IRAM, 300 rue de la Piscine, Domaine Universitaire, F-38406 St. Martin d'Hères, France

Using ALMA observations of ^{12}CO(2–1), ^{28}SiO(5–4) and $^{32}SO_2(16_{6,10}–17_{5,13})$ emissions of the circumstellar envelope of AGB star EP Aqr, we describe the morpho-kinematics governing the nascent wind. Main results are: 1) Two narrow polar structures, referred to as jets, launched from less than 25 au away from the star, build up between $\sim$ 20 au and $\sim$ 100 au to a velocity of $\sim$ 20 km s^{-1}. They fade away at larger distances and are barely visible in CO data. 2) SO_2, SiO and CO emissions explore radial ranges reaching respectively $\sim$ 30 au, 250 au and 1000 au from the star, preventing the jets to be detected in SO_2 data. 3) Close to the star photosphere, rotation (undetected in SiO and CO data) and isotropic radial expansion combine with probable turbulence to produce a broad SO_2 line profile ($\sim$ 7.5 km s^{-1} FWHM). 4) A same axis serves as axis of rotation close to the star, as jet axis and as axi-symmetry axis at large distances. 5) A radial wind builds up at distances up to $\sim$ 300 au from the star, with larger velocity near polar than equatorial latitudes. 6) A sharp depletion of SiO and CO emissions, starting near the star, rapidly broadens to cover the whole blue-western quadrant, introducing important asymmetry in the CO and particularly SiO observations. 7) The ^{12}C/^{13}C abundance ratio is measured as 9 ± 2. 8) Plausible interpretations are discussed, in particular assuming the presence of a companion.

Accepted for publication in MNRAS
Available from https://arxiv.org/abs/1905.02715

The type II-Plateau supernova 2017eaw in NGC 6946 and its red supergiant progenitor

Schuyler D. Van Dyk[1], *WeiKang Zheng*[2], *Justyn R. Maund*[3], *Thomas G. Brink*[2], *Sundar Srinivasan*[4,5], *Jennifer E. Andrews*[6], *Nathan Smith*[6], *Douglas C. Leonard*[7], *Viktoriya Morozova*[8], *Alexei V. Filippenko*[2,9], *Brody Conner*[10], *Dan Milisavljevic*[10], *Thomas de Jaeger*[2], *Knox S. Long*[11,12], *Howard Isaacson*[2], *Ian J.M. Crossfield*[13], *Molly R. Kosiarek*[14,15], *Andrew W. Howard*[16], *Ori D. Fox*[11], *Patrick L. Kelly*[17], *Anthony L. Piro*[18], *Stuart P. Littlefair*[3], *Vik S. Dhillon*[3,19], *Richard Wilson*[20], *Timothy Butterley*[20], *Sameen Yunus*[2], *Sanyum Channa*[2], *Benjamin T. Jeffers*[2], *Edward Falcon*[2], *Timothy W. Ross*[2], *Julia C. Hestenes*[2], *Samantha M. Stegman*[2], *Keto Zhang*[2] *and Sahana Kumar*[2,21]

[1]Caltech/*Spitzer* Science Center, Caltech/IPAC, Mailcode 100-22, Pasadena, CA 91125, USA

[2]Department of Astronomy, University of California, Berkeley, CA 94720-3411, USA

[3]Department of Physics and Astronomy, University of Sheffield, Hicks Building, Hounsfield Road, Sheffield S3 7RH, UK

[4]Institute of Astronomy & Astrophysics, Academia Sinica, 11F, Astronomy-Mathematics Building, No. 1, Roosevelt Rd., Sec. 4, Taipei 10617, Taiwan, Republic of China

[5]Instituto de Radioastronomía y Astrofísica, Universidad Nacional Autonóma de México, Antigua Carretera a Pátzcuaro # 8701 Ex-Hda. San José de la Huerta, Morelia, Michoacán, México C.P. 58089

[6]Steward Observatory, University of Arizona, 933 N. Cherry Avenue, Tucson, AZ 85721, USA

[7]Department of Astronomy, San Diego State University, San Diego, CA 92182-1221, USA

[8]Department of Astrophysical Sciences, Princeton University, Princeton, NJ 08544, USA

[9]Miller Senior Fellow, Miller Institute for Basic Research in Science, University of California, Berkeley, CA 94720, USA

[10]Department of Physics and Astronomy, Purdue University, 525 Northwestern Avenue, West Lafayette, IN 47907, USA

[11]Space Telescope Science Insitute, 3700 San Martin Drive, Baltimore, MD 21218, USA

[12]Eureka Scientific, Inc. 2452 Delmer Street, Suite 100, Oakland, CA 94602-3017, USA

[13]Department of Physics, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Cambridge, MA, USA

[14]University of California Santa Cruz, Santa Cruz, CA, 95064, USA

[15]NSF Graduate Research Fellow

[16]California Institute of Technology, Pasadena, CA 91125, USA

[17]College of Science & Engineering, Minnesota Institute for Astrophysics, University of Minnesota, 115 Union St. SE, Minneapolis, MN 55455 USA

[18]The Observatories of the Carnegie Institution for Science, 813 Santa Barbara St., Pasadena, CA 91101, USA

[19]Instituto de Astrofísica de Canarias, E-38205 La Laguna, Tenerife, Spain

[20]Center for Advanced Instrumentation, Department of Physics, University of Durham, South Road, Durham DH1 3LE, UK

[21]Department of Physics, Florida State University, 77 Chieftain Way, Tallahassee, Florida 32306, USA

We present extensive optical photometric and spectroscopic observations, from 4 to 482 days after explosion, of the type II-Plateau (II-P) supernova (SN) 2017eaw in NGC 6946. SN 2017eaw is a normal SN II-P intermediate in properties between, for example, SN 1999em and SN 2012aw and the more luminous SN 2004et, also in NGC 6946. We have determined that the extinction to SN 2017eaw is primarily due to the Galactic foreground and that the SN site metallicity is likely subsolar. We have also independently confirmed a tip-of-the-red-giant-branch (TRGB) distance to NGC 6946 of 7.73 ± 0.78 Mpc. The distances to the SN that we have also estimated via both the standardized candle method and expanding photosphere method corroborate the TRGB distance. We confirm the SN progenitor identity in pre-explosion archival *Hubble* Space Telescope (HST) and *Spitzer* Space Telescope images, via imaging of the SN through our HST Target of Opportunity program. Detailed modeling of the progenitor's spectral energy distribution indicates that the star was a dusty, luminous red supergiant consistent with an initial mass of ~ 15 $M_\odot$.

Published in The Astrophysical Journal
Available from https://arxiv.org/abs/1903.03872
and from https://iopscience.iop.org/article/10.3847/1538-4357/ab1136/meta

Precise radial velocities of giant stars. XII. Evidence against the proposed planet Aldebaran b

Katja Reichert[1,2], Sabine Reffert[1], Stephan Stock[1], Trifon Trifonov[3] and Andreas Quirrenbach[1]

[1]Landessternwarte, Zentrum für Astronomie der Universität Heidelberg, Königstuhl 12, 69117, Heidelberg, Germany

[2]Astronomisches Rechen-Institut, Zentrum für Astronomie der Universität Heidelberg, Mönchhofstraße 12-14, 69120, Heidelberg, Germany

[3]Max-Planck-Institut für Astronomie, Königstuhl 17, 69117, Heidelberg, Germany

Context: Radial-velocity variations of the K giant star Aldebaran (α Tau) were first reported in the early 1990s. After subsequent analyses, the radial-velocity variability with a period of $\sim$ 629 d has recently been interpreted as caused by a planet of several Jovian masses.
Aims: We want to further investigate the hypothesis of an extrasolar planet around Aldebaran.
Methods: We combine 165 new radial-velocity measurements from Lick Observatory with seven already published data sets comprising 373 radial-velocity measurements. We perform statistical analyses and investigate whether a Keplerian model properly fits the radial velocities. We also perform a dynamical stability analysis for a possible two-planet solution. Furthermore, the possibility of oscillatory convective modes as cause for the observed radial-velocity variability is discussed.
Results: As best Keplerian fit to the combined radial-velocity data we obtain an orbit for the hypothetical planet with a smaller period ($P = 607$ d) and a larger eccentricity ($e = 0.33 \pm 0.04$) than the previously proposed one. However, the residual scatter around that fit is still large, with a standard deviation of 117 m s^{-1}. In 2006/2007, the statistical power of the $\sim$ 620 d period showed a temporary but significant decrease. Plotting the growth of power in reverse chronological order reveals that a period around 620 d is clearly present in the newest data but not in the data taken before $\sim$ 2006. Furthermore, an apparent phase shift between radial-velocity data and orbital solution is observable at certain times. A two-planet Keplerian fit matches the data considerably better than a single-planet solution, but poses severe dynamical stability issues.
Conclusions: The radial-velocity data from Lick Observatory do not further support but in fact weaken the hypothesis of a substellar companion around Aldebaran. Oscillatory convective modes might be a plausible alternative explanation of the observed radial-velocity variations.

Published in A&A 625, A22 (2019)
Available from https://arxiv.org/abs/1903.09157
and from https://www.aanda.org/articles/aa/abs/2019/05/aa34028-18/aa34028-18.html

The post-common-envelope binary nucleus of the planetary nebula IC 4776: Neither an anomalously long orbital period nor a Wolf–Rayet binary

B. Miszalski[1,2], R. Manick[3,1], H. Van Winckel[3] and Mikołajewska[4]

[1]South African Astronomical Observatory, P.O. Box 9, Observatory, 7935, South Africa

[2]Southern African Large Telescope Foundation, P.O. Box 9, Observatory, 7935, South Africa

[3]Institute of Astronomy, K.U. Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium

[4]Nicolaus Copernicus Astronomical Center, Polish Academy of Sciences, Bartycka 18, PL-00716 Warsaw, Poland

The orbital period distribution of close binary stars consisting of a white dwarf and a main-sequence star (WDMS) is a powerful observational constraint on population synthesis models of the poorly understood common-envelope (CE) interaction. Models have often struggled to reproduce the small number of post-CE WDMS binaries with anomalously long orbital periods greater than $\sim$ 4 d, though recent studies suggest that in longer period systems recombination energy may help contribute to the efficient ejection of the CE. Planetary nebulæ (PNe) are an emerging source of rare long period post-CE binaries which can act as powerful complementary constraints on population synthesis models to more traditional post-CE binary populations. A tentative 9.0 d orbital period was recently proposed for the central star of the PN IC 4776, potentially one of the longest periods observed in post-CE WDMS binaries. Here we present SALT HRS observations of IC 4776 that rule out a 9.0 d orbital period, as well as the previously suggested Wolf–Rayet classification of the primary. The SALT HRS data establish a 3.11 d orbital period and rule out Of and Wolf–Rayet

primary spectral types. Assuming a mass of 0.6 $M_\odot$ for the primary and an orbital inclination matching the nebula orientation, we find a companion mass of 0.22 ± 0.03 $M_\odot$, most likely corresponding to an M4 V companion. The orbital period of IC 4776 is still consistent with findings of abundance discrepancy factor (ADF) studies of post-CE PNe, but any trends in the ADF distribution derived from the sample remain significantly biased by selection effects.

Accepted for publication in MNRAS
Available from https://arxiv.org/abs/1905.03714

First astrophysical detection of the helium hydride ion (HeH^+)

R. Güsten[1], H. Wiesemeyer[1], D. Neufeld[2], K.M. Menten[1], U.U. Graf[3], K. Jacobs[3], B. Klein[1,4], O. Ricken[1], C. Risacher[1,5] and J. Stutzki[3]

[1]Max-Planck Institut für Radioastronomie, Bonn, Germany
[2]The Johns Hopkins University, Baltimore, MD, USA
[3]Physikalisches Institut, Universität zu Köln, Cologne, Germany
[4]University of Applied Sciences Bonn–Rhein–Sieg, Sankt Augustin, Germany
[5]Institut de Radioastronomie Millimétrique, Saint-Martin-d'Hères, France

During the dawn of chemistry when the temperature of the young Universe had fallen below ~ 4000 K, the ions of the light elements produced in Big Bang nucleosynthesis recombined in reverse order of their ionization potential. With its higher ionization potentials, He^{++} (54.5 eV) and He^+ (24.6 eV) combined first with free electrons to form the first neutral atom, prior to the recombination of hydrogen (13.6 eV). At that time, in this metal-free and low-density environment, neutral helium atoms formed the Universe's first molecular bond in the helium hydride ion HeH^+, by radiative association with protons ($He + H^+ \rightarrow HeH^+ + h\nu$). As recombination progressed, the destruction of HeH^+ ($HeH^+ + H \rightarrow He + H_2^+$) created a first path to the formation of molecular hydrogen, marking the beginning of the Molecular Age. Despite its unquestioned importance for the evolution of the early Universe, the HeH^+ molecule has so far escaped unequivocal detection in interstellar space. In the laboratory, the ion was discovered as long ago as 1925, but only in the late seventies was the possibility that HeH^+ might exist in local astrophysical plasmas discussed. In particular, the conditions in planetary nebulæ were shown to be suitable for the production of potentially detectable HeH^+ column densities: the hard radiation field from the central hot white dwarf creates overlapping Strömgren spheres, where HeH^+ is predicted to form, primarily by radiative association of He^+ and H. With the GREAT spectrometer onboard SOFIA, the HeH^+ rotational ground-state transition at $\lambda 149.1\ \mu$m is now accessible. We report here its detection towards the planetary nebula NGC 7027.

Published in Nature, 568, 357 (2019)
Available from https://arxiv.org/abs/1904.09581

Intermediate Luminosity Optical Transients (ILOTs) from merging giants

Ran Segev[1], Efrat Sabach[1] and Noam Soker[1]

[1]Technion, Israel

We study the formation of intermediate luminosity optical transients (ILOTs) from the merger of two cool giant stars. For the two stars to merge when both are in their giant phases the stars must have close masses at their zero age main sequence, and the orbital separation must be in the right range. After the two giants merge, the two cores spirals-in toward each other within a common envelope. This process ejects mass that powers radiation by recombination and by collision with previously ejected mass. Using the stellar evolution numerical code MESA for two binary systems with stellar masses of (15,15.75 $M_\odot$) and (31,31.5 $M_\odot$), we find that the merger of the two cores releases gravitational energy that marginally ejects the entire common envelope. This implies that in many cases the two cores merge, i.e., a fatal common envelope evolution, leading to a somewhat more luminous ILOT. Overall, we estimate that a typical ILOT from merger of two cool giant stars lasts for several months to several years and has a typical average luminosity of $L(\mathrm{ILOT}) = 10^6(M(\mathrm{CE})/10\mathrm{M}_\odot)\mathrm{L}_\odot$, where $M(\mathrm{CE})$ is the common envelope mass. Due to the merger-driven massive outflow, we expect dust formation and a very red ILOT, possibly even an infrared luminous and undetectable in the visible. As the giants cannot launch jets, we expect the descendant nebula formed by the merger process to have an elliptical morphology but with no bipolar lobes.

Submitted to AAS Journals
Available from https://arxiv.org/abs/1904.11331

Atmospheres and UV environments of Earth-like planets throughout post-main-sequence evolution

Thea Kozakis[1] *and Lisa Kaltenegger*[1]

[1]Carl Sagan Institute, Cornell University, USA

During the post-main-sequence (post-MS) phase of stellar evolution, the orbital distance of the habitable zone (HZ), which allows for liquid surface water on terrestrial planets, moves out past the system's original frost line, providing an opportunity for outer planetary system surface habitability. We use a 1D coupled climate/ photochemistry code to study the impact of the stellar environment on the planetary atmospheres of Earth-like planets/moons throughout its time in the post-MS HZ. We also explore the ground UV environments of such planets/moons and compare them to Earth's. We model the evolution of star–planet systems with host stars ranging from 1.0 to 3.5 $\mathrm{M}_\odot$ throughout the post-MS, calculating stellar mass loss and its effects on planetary orbital evolution and atmospheric erosion. The maximum amount of time a rocky planet can spend continuously in the evolving post-MS HZ ranges between 56 and 257 Myr for our grid stars. Thus, during the post-MS evolution of their host star, subsurface life on cold planets and moons could become remotely detectable once the initially frozen surface melts. Frozen planets or moons, like Europa in our solar system, experience a relatively stable environment on the horizontal branch of their host star's evolution for millions of years.

Published in The Astrophysical Journal
Available from https://arxiv.org/abs/1904.10474

Using the tip of the red giant branch as a distance indicator in the near infrared

Kristen McQuinn[1,2]

[1]Rutgers University, USA
[2]University of Texas at Austin, USA

The tip of the red giant branch (TRGB) is a well-established standard candle used to measure distances to nearby galaxies. The TRGB luminosity is typically measured in the I-band, where the luminosity has little dependency on stellar age or stellar metallicity. As the TRGB is brighter at wavelengths redder than the I-band, observational gains can be made if the TRGB luminosity can be robustly calibrated at longer wavelengths. This is of particular interest given the infrared capabilities that will be available with the *James Webb* Space Telescope and an important calibration consideration for using TRGB distances as part of an independent measurement of the Hubble constant. Here, we use simulated photometry to investigate the dependency of the TRGB luminosity on stellar age and metallicity as a function of wavelength (λ475 nm – 4.5 μm). We find intrinsic variations in the TRGB magnitude to increase from a few hundredths of a magnitude at λ800–900 nm to ~ 0.6 mag by λ1.5 μm. We show that variations at the longer infrared wavelengths can be reduced to 0.02–0.05 mag (1–2% accuracy in distance) with careful calibrations that account for changes in age and metal content. These represent the minimum uncertainties; observational uncertainties will be higher. Such calibration efforts may also provide independent constraints of the age and metallicity of stellar halos

where TRGB distances are best measured. At 3.6 and 4.5 μm, the TRGB magnitude is predicted to vary by ~ 0.15 mag even after corrections, making these wavelengths less suitable for precision distances.

Submitted to ApJ
Available from https://arxiv.org/abs/1904.01571

Resolving the extended stellar atmospheres of asymptotic giant branch stars at (sub)millimetre wavelengths

Wouter Vlemmings[1], *Theo Khouri*[1] *and Hans Olofsson*[1]

[1]Department of Space, Earth and Environment, Chalmers University of Technology, Sweden

Context: The initial conditions for mass loss during the asymptotic giant branch (AGB) phase are set in their extended atmospheres, where, among others, convection and pulsation driven shocks determine the physical conditions.
Aims: High resolution observations of AGB stars at (sub)millimetre wavelengths can now directly determine the morphology, activity, density, and temperature close to the stellar photosphere.
Methods: We used Atacama Large Millimeter/submillimeter Array (ALMA) high angular resolution observations to resolve the extended atmospheres of four of the nearest AGB stars: W Hya, Mira A, R Dor, and R Leo. We interpreted the observations using a parameterised atmosphere model.
Results: We resolve all four AGB stars and determine the brightness temperature structure between 1 and 2 stellar radii. For W Hya and R Dor we confirm the existence of hotspots with brightness temperatures > 3000 to 10000 K. All four stars show deviations from spherical symmetry. We find variations on a timescale of days to weeks, and for R Leo we directly measure an outward motion of the millimetre wavelength surface with a velocity of at least 10.6 ± 1.4 km s^{-1}. For all objects but W Hya we find that the temperature–radius and size–frequency relations require the existence of a (likely inhomogeneous) layer of enhanced opacity.
Conclusions: The ALMA observations provide a unique probe of the structure of the extended AGB atmosphere. We find highly variable structures of hotspots and likely convective cells. In the future, these observations can be directly compared to multi-dimensional chromosphere and atmosphere models that determine the temperature, density, velocity, and ionisation structure between the stellar photosphere and the dust formation region. However, our results show that for the best interpretation, both very accurate flux calibration and near-simultaneous observations are essential.

Accepted for publication in Astronomy & Astrophysics
Available from https://arxiv.org/abs/1904.06374

Barium and related stars, and their white-dwarf companions. II. Main-sequence and subgiant stars

A. Escorza[1,2], *D. Karinkuzhi*[2,3], *A. Jorissen*[2], *L. Siess*[2], *H. Van Winckel*[1], *D. Pourbaix*[2], *C. Johnston*[1], *B. Miszalski*[4,5], *G-M. Oomen*[1,6], *M. Abdul-Masih*[1], *H.M.J. Boffin*[7], *P. North*[8], *R. Manick*[1,4], *S. Shetye*[2,1] *and J. Mikołajewska*[9]

[1]Institute of Astronomy, K.U. Leuven, Celestijnenlaan 200D, B-3001 Leuven, Belgium

[2]Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, Boulevard du Triomphe, B-1050 Bruxelles, Belgium

[3]Department of physics, Jnana Bharathi Campus, Bangalore University, Bangalore 560056, India

[4]South African Astronomical Observatory, P.O. Box 9, Observatory 7935, South Africa

[5]Southern African Large Telescope Foundation, P.O. Box 9, Observatory 7935, South Africa

[6]Department of Astrophysics/IMAPP, Radboud University, P.O. Box 9010, 6500 GL Nijmegen, The Netherlands

[7]ESO, Karl-Schwarzschild-str. 2, 85748 Garching bei München, Germany

[8]Institut de Physique, Laboratoire d'astrophysique, École Polytechnique Fédérale de Lausanne (EPFL), Observatoire, 1290 Versoix, Switzerland

[9]N. Copernicus Astronomical Center, Polish Academy of Sciences, Bartycka 18, 00-716 Warsaw, Poland

Barium (Ba) dwarfs and CH subgiants are the less evolved analogues of Ba and CH giants. They are F- to G-type main-sequence stars polluted with heavy elements by their binary companions when the companion was on the asymptotic

giant branch (AGB). This companion is now a white dwarf that in most cases cannot be directly detected. We present a large systematic study of 60 objects classified as Ba dwarfs or CH subgiants. Combining radial-velocity measurements from HERMES and SALT high-resolution spectra with radial-velocity data from CORAVEL and CORALIE, we determine the orbital parameters of 27 systems. We also derive their masses by comparing their location in the Hertzsprung–Russell diagram with evolutionary models. We confirm that Ba dwarfs and CH subgiants are not at different evolutionary stages, and that they have similar metallicities, despite their different names. Additionally, Ba giants appear significantly more massive than their main-sequence analogues. This is likely due to observational biases against the detection of hotter main-sequence post-mass-transfer objects. Combining our spectroscopic orbits with the *Hipparcos* astrometric data, we derive the orbital inclination and the mass of the WD companion for four systems. Since this cannot be done for all systems in our sample yet (but should be possible with upcoming Gaia data releases), we also analyse the mass-function distribution of our binaries. We can model this distribution with very narrow mass distributions for the two components and random orbital orientations on the sky. Finally, based on BINSTAR evolutionary models, we suggest that the orbital evolution of low-mass Ba systems can be affected by a second phase of interactions along the red giant branch of the Ba star, which impact the eccentricities and periods of the giants.

Accepted for publication in Astronomy & Astrophysics
Available from https://arxiv.org/abs/1904.04095

Photometry of symbiotic stars – XIV

M. Sekeráš[1], *A. Skopal*[1], *S. Shugarov*[1,2], *N. Shagatova*[1], *E. Kundra*[1], *R. Komžík*[1], *M. Vrašťák*[3], *S. P. Peneva*[4], *E. Semkov*[4] *and R. Stubbings*[5]

[1]Astronomical Institute of the Slovak Academy of Sciences, 059 60 Tatranska Lomnice, Slovakia
[2]P.K. Sternberg Astronomical Institute, M.V. Lomonosov Moscow State University, Russia
[3]Private observatory, 03401 Liptovská Štiavnica, The Slovak Republic
[4]Institute of Astronomy and National Astronomical Observatory, Bulgarian Academy of Sciences, 72 Tsarigradsko Shose blvd., BG-1784 Sofia, Bulgaria
[5]Tetoora Observatory, 2643 Warragul–Korumburra Road, Tetoora Road, Victoria 3821, Australia

We present new multicolour $UBVR_CI_C$ photometric observations of symbiotic stars, EG And, Z And, BF Cyg, CH Cyg, CI Cyg, V1016 Cyg, V1329 Cyg, AG Dra, RS Oph, AG Peg, AX Per, and the newly discovered (August 2018) symbiotic star HBHA 1704−05, we carried out during the period from 2011.9 to 2018.75. Historical photographic and visual/V data were collected for HBHA 1704−05, FG Ser and AE Ara, AR Pav, respectively. The main aim of this paper is to present our original observations of symbiotic stars and to describe the most interesting features of their light curves. For example, periodic variations, rapid variability, minima, eclipses, outbursts, apparent changes of the orbital period, etc. Our measurements were obtained by the classical photoelectric photometry (till 2016.1) and the CCD photometry. Main results of our monitoring program are summarized and some specific characteristics are pointed out for future investigation.

Published in Astronomical Observatory Skalnaté Pleso, 49, 19 (2019)
Available from https://arxiv.org/abs/1904.05555
and from https://www.astro.sk/caosp/Eedition/FullTexts/vol49no1/pp19-66.pdf

Maser flare simulations from oblate and prolate clouds

M.D. Gray[1], *J. Baggott*[1], *J. Westlake*[1] *and S. Etoka*[1]

[1]Jodrell Bank Centre for Astrophysics, School of Physics and Astronomy, University of Manchester, M13 9PL, UK

We investigated, through numerical models, the flaring variability that may arise from the rotation of maser clouds of approximately spheroidal geometry, ranging from strongly oblate to strongly prolate examples. Inversion solutions

were obtained for each of these examples over a range of saturation levels from unsaturated to highly saturated. Formal solutions were computed for rotating clouds with many randomly chosen rotation axes, and corresponding averaged maser light curves plotted with statistical information. The dependence of results on the level of saturation and on the degree of deformation from the spherical case were investigated in terms of a variability index and duty cycle. It may be possible to distinguish observationally between flares from oblate and prolate objects. Maser flares from rotation are limited to long timescales (at least a few years) and modest values of the variability index (≤ 100), and can be aperiodic or quasi-periodic. Rotation is therefore not a good model for H_2O variability on timescales of weeks to months, or of truly periodic flares.

Published in MNRAS, 486, 4216 (2019)
Available from https://arxiv.org/abs/1904.10347

A new radio molecular line survey of planetary nebulæ: HNC/HCN as a diagnostic of ultraviolet irradiation

J. Bublitz[1,2], J.H. Kastner[2], M. Santander-García[3], V. Bujarrabal[3], J. Alcolea[3] and R. Montez Jr.[4]

[1]Institut de Planétologie et d'Astrophysique de Grenoble (IPAG) UMR 5274, F-38041, Grenoble, France
[2]School of Physics and Astronomy, Center for Imaging Science, and Laboratory for Multiwavelength Astrophysics, Rochester Institute of Technology, 54 Lomb Memorial Drive, Rochester, NY 14623, USA
[3]Observatorio Astronómico Nacional, Alfonso XII, 3, 28014, Madrid, Spain
[4]Smithsonian Astrophysical Observatory, 60 Garden Street, Cambridge, MA 02138, USA

Certain planetary nebulæ contain shells, filaments, or globules of cold gas and dust whose heating and chemistry are likely driven by UV and X-ray emission from their central stars and from wind-collision-generated shocks. We present the results of a survey of molecular line emission in the 88–236 GHz range from nine nearby (< 1.5 kpc) planetary nebulæ spanning a range of UV and X-ray luminosities, using the 30 m telescope of the Institut de Radioastronomie Millimétrique. Rotational transitions of thirteen molecules, including CO isotopologues and chemically important trace species, were observed and the results compared with and augmented by previous studies of molecular gas in PNe. Lines of the molecules HCO^+, HNC, HCN, and CN, which were detected in most objects, represent new detections for four planetary nebulæ in our study. Specifically, we present the first detections of ^{13}CO(1–0, 2–1), HCO^+, CN, HCN, and HNC in NGC 6445; HCO^+ in BD +30°3639; ^{13}CO(2–1), CN, HCN, and HNC in NGC 6853; and ^{13}CO(2–1) and CN in NGC 6772. Flux ratios were analyzed to identify correlations between the central star and/or nebular UV and X-ray luminosities and the molecular chemistries of the nebulæ. This analysis reveals a surprisingly robust dependence of the HNC/HCN line ratio on PN central star UV luminosity. There exists no such clear correlation between PN X-rays and various diagnostics of PN molecular chemistry. The correlation between HNC/HCN ratio and central star UV luminosity demonstrates the potential of molecular emission line studies of PNe for improving our understanding of the role that high-energy radiation plays in the heating and chemistry of photodissociation regions.

Accepted for publication in Astronomy & Astrophysics
Available from https://arxiv.org/abs/1904.08440

Planetary nebulæ and how to find them: color identification in big broadband surveys

George Vejar[1,5], Rodolfo Montez Jr.[2], Margaret Morris[4] and Keivan G. Stassun[1,3]

[1]Department of Physics and Astronomy, Vanderbilt University, Nashville, TN 37235, USA
[2]Center for Astrophysics – Harvard & Smithsonian, Cambridge, MA 02138, USA
[3]Department of Physics, Fisk University, Nashville, TN 37208, USA
[4]Scripps Institution of Oceanography, U.C. San Diego, San Diego, CA 92037, USA
[5]LSSTC Data Science Fellow

Planetary nebulæ (PNe) provide tests of stellar evolution, can serve as tracers of chemical evolution in the Milky

Way and other galaxies, and are also used as a calibrator of the cosmological distance ladder. Current and upcoming large scale photometric surveys have the potential to complete the census of PNe in our galaxy and beyond, but it is a challenge to disambiguate partially or fully unresolved PNe from the myriad other sources observed in these surveys. Here we carry out synthetic observations of nebular models to determine *ugrizy* color–color spaces that can successfully identify PNe among billions of other sources. As a primary result we present a grid of synthetic absolute magnitudes for PNe at various stages of their evolution, and we make comparisons with real PNe colors from the Sloan Digital Sky Survey. We find that the $r-i$ versus $g-r$, and the $r-i$ versus $u-g$, color–color diagrams show the greatest promise for cleanly separating PNe from stars, background galaxies, and quasars. Finally, we consider the potential harvest of PNe from upcoming large surveys. For example, for typical progenitor host star masses of ~ 3 $M_\odot$, we find that the Large Synoptic Survey Telescope (LSST) should be sensitive to virtually all PNe in the Magellanic Clouds with extinction up to A_V of ~ 5 mag; out to the distance of Andromeda, LSST would be sensitive to the youngest PNe (age less than ~ 6800 yr) and with A_V up to 1 mag.

Accepted for publication in The Astrophysical Journal
Available from https://arxiv.org/abs/1905.06347

The *s*-process enriched star HD 55496: origin from a globular cluster or from the tidal disruption of a dwarf galaxy?

C.B. Pereira[1], *N.A. Drake*[1,2,3] *and F. Roig*[1]

[1]Observatório Nacional / MCTIC, Brazil
[2]Laboratory of Observational Astrophysics, Saint Petersburg State University, Universitetski pr. 28, Petrodvoretz 198504, Saint Petersburg, Russia
[3]Laboratório Nacional de Astrofísica / MCTIC, Brazil

We present a new abundance analysis of HD 55496, previously known as a metal-poor barium star. We found that HD 55496 has a metallicity [Fe/H] = −1.55 and is *s*-process enriched. We find that HD 55496 presents four chemical peculiarities: (i) a Na–O abundance anti-correlation; (ii) it is aluminum rich; (iii) it is carbon poor for a *s*-process enriched star and (iv) the heavy 2nd *s*-process peak elements, such as Ba, La, Ce, and Nd, present smaller abundances than the lighter *s*-process elements, such as Sr, Y and Zr, which is not usually observed among the chemically-peculiar binary stars at this metallicity. The heavy-element abundance pattern suggests that the main source of the neutrons is the ^{22}Ne(α,n)^{25}Mg reaction. Taken all these abundance evidence together into consideration, this strongly suggests that HD 55496 is a "second generation of globular cluster star" formed from gas already strongly enriched in *s*-process elements and now is a field halo object. Our dynamical analysis, however, indicates that the past encounter probabilities with the known globular clusters is very small ($\leq 6\%$). This evidence, together with the fact of having a retrograde motion, points to a halo intruder possibly originated from the tidal disruption of a dwarf galaxy.

Accepted for publication in MNRAS
Available from https://arxiv.org/abs/1905.08141

Barium and related stars, and their white-dwarf companions I. Giant stars

A. Jorissen[1], *H.M.J. Boffin*[2], *D. Karinkuzhi*[1,3], *S. Van Eck*[1], *A. Escorza*[1,4] *and H. Van Winckel*[4]

[1]Institut d'Astronomie et d'Astrophysique, Université Libre de Bruxelles, Belgium
[2]ESO, Garching bei München, Germany
[3]Department of Physics, Bangalore University, India
[4]Institute of Astronomy, K.U. Leuven, Belgium

Barium and S stars without technetium are red giants suspected of being all members of binary systems. This paper provides both long-term and revised, more accurate orbits for barium and S stars adding to previously published ones. The sample of barium stars with strong anomalies comprise all such stars present in the Lü et al. catalogue. Orbital elements are derived from radial velocities collected from a long-term radial-velocity monitoring performed with the HERMES spectrograph mounted on the Mercator 1.2-m telescope. These new measurements were combined with older CORAVEL measurements. With the aim of investigating possible correlations between orbital properties and abundances, we also collected a set of abundances as homogeneous as possible for barium stars with orbital elements. We find orbital motion for all barium and extrinsic S stars monitored. We obtain the longest period known so far for a spectroscopic binary involving an S star, namely 57 Peg with a period of the order of 100–500 yr. We present the mass distribution for the barium stars, which ranges from 1 to 3 $M_\odot$, with a tail extending up to 5 $M_\odot$ in the case of mild barium stars. This high-mass tail comprises mostly high-metallicity objects ([Fe/H] ≥ -0.1). Mass functions are compatible with WD companions whose masses range from 0.5 to 1 $M_\odot$. Strong barium stars have a tendency to be found in systems with shorter periods than mild barium stars, although this correlation is rather lose, metallicity and WD mass playing a role as well. Using the initial–final mass relationship established for field WDs, we derived the distribution of the mass ratio $q' = M_{\rm AGB,ini}/M_{\rm Ba}$ (where $M_{\rm AGB,ini}$ is the WD progenitor initial mass, i.e., the mass of the system former primary component) which is a proxy for the initial mass ratio (the more so, the less mass the barium star has accreted). It appears that the distribution of q' is highly non uniform, and significantly different for mild and strong barium stars, the latter being characterized by values mostly in excess of 1.4, whereas mild barium stars occupy the range 1–1.4. The orbital properties presented in this paper pave the way for a comparison with binary-evolution models.

Accepted for publication in A&A
Available from https://arxiv.org/abs/1904.03975

Carbon stars with increased oxygen and nitrogen abundances: hydrostatic dust-free model atmospheres

Bernhard Aringer[1,3], Paola Marigo[1], Walter Nowotny[3], Léo Girardi[2], Marko Mecina[3] and Ambra Nanni[1,4]

[1]Dipartimento di Fisica e Astronomia Galileo Galilei, Università di Padova, Vicolo dell'Osservatorio 3, I-35122 Padova, Italy
[2]Osservatorio Astronomico di Padova – INAF, Vicolo dell'Osservatorio 5, I-35122 Padova, Italy
[3]Department of Astrophysics, University of Vienna, Türkenschanzstraße 17, A-1180 Wien, Austria
[4]Aix Marseille Univ., CNRS, CNES, LAM, Marseille, France

We have computed a grid of hydrostatic spherical COMARCS models for C stars covering metallicities from [Z/H] = 0 to −2 and values of the carbon excess [C–O] from 6.41 to 9.15, plus some temperature sequences, where the amount of oxygen and nitrogen is increased relative to a scaled solar element mixture. Such abundance variations may appear during the late stages of stellar evolution. Our study covers changes of [O/Z] and [N/Z] going up to +0.5. Based on the atmospheric structures we have calculated synthetic spectra and photometry for all of the models in a consistent way.
The sequences with changed [O/Z] and [N/Z] can be used to derive correction terms, which are applied to the colours predicted for a certain combination of effective temperature, surface gravity, metallicity and carbon excess. If one neglects these shifts in case of a variable oxygen amount, taking [C–O] instead of C/O gives much better results, since the first quantity dominates the formation of many important molecular species. For the warmer C giants with weaker pulsation it is in principle possible to determine [C–O], [O/Z] or [N/Z] from high resolution spectra, when the opacities in the radiative transfer calculations for the models and observable properties are treated consistently. The corresponding changes due to the abundances often become significantly larger than the deviations caused by uncertainties of the stellar parameters or by an optically thin dust shell. Photometric data and low or medium resolution spectra are not sufficient to derive the mentioned quantities.

Accepted for publication in MNRAS
Available from https://arxiv.org/abs/1905.09106
and from http://stev.oapd.inaf.it/atm

On massive dust clumps in the envelope of the red supergiant VY Canis Majoris

Tomasz Kamiński[1]

[1]Center for Astrophysics – Harvard & Smithsonian, USA

The envelope of the red supergiant VY CMa has long been considered an extreme example of episodic mass loss that is possibly taking place in other cool and massive evolved stars. Recent (sub-)millimeter observations of the envelope revealed the presence of massive dusty clumps within 800 mas from the star which reinforce the picture of drastic mass-loss phenomena in VY CMa. We present new ALMA observations at an angular resolution of 0.″1 and at an unprecedented sensitivity that reveal further details about the dusty clumps. We resolve more discrete features and identify a submillimeter counterpart of a more distant Clump SW known from visual observations. The brightest clump, named C, is marginally resolved in the observations. Gas seen against the resolved continuum emission of clump C produces a molecular spectrum in absorption, in lines of mainly sulfur-bearing species. Except for SW Clump, no molecular emission is found to be associated with the dusty clumps and we propose that the dusty structures have an atypically low gas content. We attempt to reproduce the properties of the dusty clumps through three-dimensional radiative-transfer modeling. Although a clump configuration explaining the observations is found, it is not unique. A very high optical depth of all clumps to the stellar radiation make the modeling very challenging and requires unrealistically high dust masses for one of them. It is suggested that the dusty features have substructures, e.g., porosity, that allows deeper penetration of stellar photons within the clumps than in a homogeneous configuration. A comparison of the estimated clumps ages to variations in the stellar visual flux for over a century suggests that the mechanism responsible for their formation is not uniquely manifested by enhanced or strongly diminished visual light. The study demonstrates that the dusty mass-loss episodes of VY CMa are indeed unparalleled among all known non-explosive stars. The origin of these episodes remains an unsolved problem.

Accepted for publication in A&A
Available from https://arxiv.org/abs/1903.09558

The mass-loss, expansion velocities and dust production rates of carbon stars in the Magellanic Clouds

Ambra Nanni[1,2], *Martin A.T. Groenewegen*[3], *Bernhard Aringer*[1], *Stefano Rubele*[1,4], *Alessandro Bressan*[5], *Jacco Th. van Loon*[6], *Steven R. Goldman*[7] *and Martha L. Boyer*[7]

[1]Dipartimento di Fisica e Astronomia Galileo Galilei, Università di Padova, Vicolo dell'Osservatorio 3, I-35122 Padova, Italy

[2]Aix Marseille Univ., CNRS, CNES, LAM, Marseille, France

[3]Koninklijke Sterrenwacht van België, Ringlaan 3, B-1180 Brussel, Belgium

[4]Osservatorio Astronomico di Padova, Vicolo dell'Osservatorio 5, I-35122 Padova, Italy

[5]SISSA, via Bonomea 265, I-34136 Trieste, Italy

[6]Lennard-Jones Laboratories, Keele University, ST5 5BG, UK

[7]STScI, 3700 San Martin Drive, Baltimore, MD 21218 USA

The properties of carbon stars in the Magellanic Clouds (MCs) and their total dust production rates are predicted by fitting their spectral energy distributions (SED) over pre-computed grids of spectra reprocessed by dust. The grids are calculated as a function of the stellar parameters by consistently following the growth for several dust species in their circumstellar envelopes, coupled with a stationary wind. Dust radiative transfer is computed taking as input the results of the dust growth calculations. The optical constants for amorphous carbon are selected in order to reproduce different observations in the infrared and optical bands of Gaia Data Release 2. We find a tail of extreme mass-losing carbon stars in the Large Magellanic Cloud (LMC) with low gas-to-dust ratios that is not present in the Small Magellanic Cloud (SMC). Typical gas-to-dust ratios are around 700 for the extreme stars, but they can be down to $\sim$ 160–200 and $\sim$ 100 for a few sources in the SMC and in the LMC, respectively. The total dust production rate for the carbon star population is $\sim 1.77 \pm 0.45 \times 10^{-5}$ M$_\odot$ yr^{-1}, for the LMC, and $\sim 2.52 \pm 0.96 \times 10^{-6}$ M$_\odot$ yr^{-1}, for the SMC. The extreme carbon stars observed with the Atacama Large Millimeter Array and their wind speed are studied in detail. For the most dust-obscured star in this sample the estimated mass-loss rate is $\sim 6.3 \times 10^{-5}$ M$_\odot$ yr^{-1}.

The grids of spectra are available at: https://ambrananni085.wixsite.com/ambrananni/online-data-1 and included in the SED-fitting python package for fitting evolved stars https://github.com/s-goldman/Dusty-Evolved-Star-Kit.

Accepted for publication in MNRAS
Available from https://arxiv.org/abs/1904.06702

Characterizing maser polarization: effects of saturation, anisotropic pumping and hyperfine structure

Boy Lankhaar[1] *and Wouter Vlemmings*[1]

[1]Chalmers University of Technology, Sweden

The polarization of masers contains information on the magnetic field strength and direction of the regions they occur in. Many maser polarization observations have been performed over the last 30 years. However, versatile maser polarization models that can aide in the interpretation of these observations are not available. We developed a program suite that can compute the polarization by a magnetic field of any non-paramagnetic maser species at arbitrarily high maser saturation. Furthermore, we investigated the polarization of masers by non-Zeeman polarizing effects. We present a general interpretive structure for maser polarization observations. We expanded existing maser polarization theories of non-paramagnetic molecules and incorporated them in a numerical modeling program suite. We present a modeling program called CHAracterizes Maser Polarization (CHAMP) that can examine the polarization of masers of arbitrarily high maser saturation and high angular momentum. Hyperfine multiplicity of the maser-transition can also be incorporated. The user is able to investigate non-Zeeman polarizing mechanisms such as anisotropic pumping and polarized incident seed radiation. We present an analysis of the polarization of $v = 1$ SiO masers and the 22-GHz water maser. We comment on the underlying polarization mechanisms, and also investigate non-Zeeman effects. We identify the regimes where different polarizing mechanisms will be dominant and present the polarization characteristics of the SiO and water masers. From the results of our calculations, we identify markers to recognize alternative polarization mechanisms. We show that comparing randomly generated linear versus circular polarization (p_L–p_V) scatter-plots at fixed magnetic field strength to the observationally obtained p_L–p_V scatter can be a promising method of ascertaining the average magnetic field strength of a large number of masers.

Accepted for publication in A&A
Available from https://arxiv.org/abs/1905.04868

Spectrum of the yellow symbiotic star LT Delphini before, during, and after the 2017 outburst

N.P. Ikonnikova[1], *M.A. Burlak*[1], *V.P. Arkhipova*[1] *and V.F. Esipov*[1]

[1]Sternberg Astronomical Institute, Moscow State University, Universitetskii pr. 13, Moscow, 119992 Russia

LT Del is a yellow symbiotic system that consists of a bright K3-type giant and a hot subdwarf with a temperature of $\sim 10^5$ K. We present the results of our spectroscopic observations of LT Del over the period 2010–2018. In 2017 the star experienced a second low-amplitude ($\Delta V \sim 0.^{\rm m}7$) outburst in the history of its studies. The emission spectrum of the star represented in the optical range by hydrogen, neutral and ionized helium lines underwent significant changes in the outburst. The fluxes in the H sc i and He I emission lines increased by a factor of 5–6, the He II λ4686 line grew by a factor of 10. According to our estimates, in the 2017 outburst, the temperature of the exciting star rose to $T_{\rm hot} \sim 130\,000$ K, while during the first 1994 outburst the change in temperature was insignificant. This suggests cool and hot outbursts of LT Del by analogy with similar events of another yellow symbiotic star, AG Dra.

Published in Astronomy Letters, 45, 217 (2019)
Available from https://arxiv.org/abs/1904.11855

Missing red supergiants and carbon burning

Tuguldur Sukhbold[1,2,3] *and Scott Adams*[4]

[1]Department of Astronomy, The Ohio State University, 140 West 18th Avenue, Columbus OH 43210, USA

[2]Center for Cosmology and AstroParticle Physics, The Ohio State University, 191 W. Woodruff Avenue, Columbus OH 43210, USA

[3]NASA Hubble Fellow

[4]Cahill Center for Astrophysics, California Institute of Technology, Pasadena, CA 91125, USA

Recent studies on direct imaging of Type II core-collapse supernova progenitors indicate a possible threshold around $M_{\rm ZAMS} \sim 16$–20 M$_\odot$, where red supergiants with larger birth masses do not appear to result in supernova explosions and instead implode directly into a black hole. In this study we argue that it is not a coincidence that this threshold closely matches the critical transition of central carbon burning in massive stars from the convective to radiative regime. In lighter stars, Carbon burns convectively in the center and result in compact final pre-supernova cores that are likely to result in explosions, while in heavier stars after the transition, it burns as a radiative flame and the stellar cores become significantly harder to explode. Using the KEPLER code we demonstrate the sensitivity of this transition to the rate of ^{12}C(α,γ)^{16}O reaction and the overshoot mixing efficiency, and we argue that the upper mass limit of exploding red supergiants could be employed to constrain uncertain input physics of massive stellar evolution calculations. The initial mass corresponding to the central carbon burning transition range from 14 to 26 M$_\odot$ in recently published models from various groups and codes, and only a few are in agreement with the estimates inferred from direct imaging studies.

Submitted to MNRAS

Available from https://arxiv.org/abs/1905.00474

Period analysis of All-Sky Automated Survey for Supernovæ (ASAS-SN) data on pulsating red giants

John R. Percy[1,2] *and Lucas Fenaux*[1]

[1]Department of Astronomy & Astrophysics, University of Toronto, Canada

[2]Dunlap Institute for Astronomy & Astrophysics, University of Toronto, Canada

The All-Sky Automated Survey for Supernovæ (ASAS-SN) has recently used over 2000 days of data to identify more than 50,000 variable stars, automatically classify these, determine periods and amplitudes for those which are periodic – part of a remarkable project to classify 412,000 known variable stars, and determine their basic properties. This information about the newly-discovered variables, along with the photometric data is freely available on-line. In this paper, we analyze ASAS-SN data on two small random samples of pulsating red giants (PRGs) in detail, and compare our results with those found by ASAS-SN. For the majority of a sample of 29 mostly semi-regular (SR) PRGs, the ASAS-SN results are incorrect or incomplete: either the ASAS-SN periods are 2, 3, or 4 times the actual period, or the ASAS-SN period is a "long secondary period" with a shorter pulsation period present, or the star is multi-periodic or otherwise complex, or the star's data are contaminated by instrumental effects. For almost all of a sample of the longest-period Mira stars (periods 640 days or more), the ASAS-SN period is actually 2 or more times the actual period. Our results are not surprising, given the very complex behaviour of PRGs.

Submitted to JAAVSO

The age and metallicity dependence of the near-infrared magnitudes of red clump stars

Hiroki Onozato[1,2], *Yoshifusa Ita*[1], *Yoshikazu Nakada*[3] *and Shogo Nishiyama*[4]

[1]Astronomical Institute, Graduate School of Science, Tohoku University, 6-3, Aramaki Aoba, Aoba-ku, Sendai, Miyagi 980-8578, Japan

[2]Nishi-Harima Astronomical Observatory, Center for Astronomy, Institute of Natural and Environmental Sciences, University of Hyogo, 407-2, Nishigaichi, Sayo-cho, Sayo-gun, Hyogo 679-5313, Japan

[3]Kiso Observatory, Institute of Astronomy, School of Science, The University of Tokyo, 10762-30 Mitake, Kiso-machi, Kiso-gun, Nagano 397-0101, Japan

[4]Miyagi University of Education, 149, Aramaki Aoba, Aoba-ku, Sendai, Miyagi 980-0845, Japan

Red clump (RC) stars are widely used as an excellent standard candle. To make them even better, it is important

to know the dependence of their absolute magnitudes on age and metallicity. We observed star clusters in the Large Magellanic Cloud to fill age and metallicity parameter space, which previous work has not observationally studied. We obtained the empirical relations of the age and metallicity dependence of absolute magnitudes M_J, M_H, and M_{K_S}, and colours $J-H$, $J-K_s$, and $H--K_s$ of RC stars, although the coefficients have large errors. Mean near-infrared magnitudes of the RC stars in the clusters show relatively strong dependence on age for young RC stars. The $J-K_s$ and $H-K_s$ colours show the nearly constant values of 0.528 ± 0.015 and 0.047 ± 0.011 mag, respectively, at least within the ages of 1.1–3.2 Gyr and [Fe/H] of -0.90 to -0.40 dex. We also confirmed that the population effects of observational data are in good agreement with the model prediction.

Published in Monthly Notices of the Royal Astronomical Society
Available from https://arxiv.org/abs/1904.12874
and from https://doi.org/10.1093/mnras/stz1192

A variationally computed IR line list for the methyl radical CH_3

Ahmad Y. Adam[1], Andrey Yachmenev[2], Sergei N. Yurchenko[3] and Per Jensen[1]

[1]Fakultät für Mathematik und Naturwissenschaften, Physikalische und Theoretische Chemie, Bergische Universität Wuppertal, D–42097 Wuppertal, Germany
[2]Center for Free-Electron Laser Science, Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, D-22607 Hamburg, Germany; The Hamburg Center for Ultrafast Imaging, Universität Hamburg, Luruper Chaussee 149, D-22761 Hamburg, Germany
[3]Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, United Kingdom

We present the first variational calculation of a hot temperature *ab initio* line list for the CH_3 radical. It is based on a high level *ab initio* potential energy surface and dipole moment surface of CH_3 in the ground electronic state. The ro-vibrational energy levels and Einstein A coefficients were calculated using the general-molecule variational approach implemented in the computer program TROVE. Vibrational energies and vibrational intensities are found to be in very good agreement with the available experimental data. The line list comprises 9,127,123 ro-vibrational states ($J \leq 40$) and 2,058,655,166 transitions covering the wavenumber range up to 10000 cm^{-1} and should be suitable for temperatures up to $T = 1500$ K.

Published in The Journal of Physical Chemistry A
Available from https://arxiv.org/abs/1905.05504
and from https://pubs.acs.org/doi/10.1021/acs.jpca.9b02919

ExoMol line lists XXXII: The rovibronic spectrum of MgO

Heng Ying Li[1], Jonathan Tennyson[1] and Sergei N. Yurchenko[1]

[1]Department of Physics and Astronomy, University College London, London WC1E 6BT, UK

Line lists for magnesium oxide are computed and extensive comparisons are made with existing experimental spectra. The LiTY line lists cover all ro-vibration transitions within the five lowest-lying electronic states ($X\,^1\Sigma^+$, $a\,^3\Pi$, $A\,^1\Pi$, $B\,^1\Sigma^+$ and $b\,^3\Sigma^+$) and five isotopologues: ^{24}Mg^{16}O, ^{25}Mg^{16}O, ^{26}Mg^{16}O, ^{24}Mg^{17}O, ^{24}Mg^{18}O, ^{24}Mg^{17}O and ^{24}Mg^{18}O. The calculation use potential energy cures, spin-orbit and electronic angular momentum couplings curves determined by fitting to empirical energy levels; these levels are reproduced to within 0.01 cm^{-1} in most cases. Computed nuclear-motion wavefunctions are combined with *ab initio* dipole moment curves to give transition intensities and excited state radiative lifetimes which are compared with laboraroty measurements. The ^{24}Mg^{16}O line list comprises 186 842 ($J \leq 320$) ro-vibronic states and 72 833 173 transitions with angular momenta, J, up to 300 and covering wavenumbers up to 33 000 cm^{-1} ($\lambda > 0.3$ μm). The line lists are suitable for temperatures up to about 5000 K. They are relevant to astrophysical studies of exoplanet atmospheres, cool stars and brown dwarfs, and are made available in electronic form at the CDS and ExoMol databases.

Published in Monthly Notices of the Royal Astronomical Society, 486, 2351 (2019)
Available from https://arxiv.org/abs/1904.12155
and from https://academic.oup.com/mnras/article-abstract/486/2/2351/5475901

ExoMol Molecular linelists – XXXIII. The spectrum of Titanium Oxide

Laura K. McKemmish[1], *Thomas Masseron*[2], *H. Jens Hoeijmakers*[3,4], *Víctor Pérez-Mesa*[2,5], *Simon L. Grimm*[3], *Sergei N. Yurchenko*[6] *and Jonathan Tennyson*[6]

[1]School of Chemistry, University of New South Wales, 2052 Sydney, Australia

[2]Instituto de Astrofísica de Canarias, E-38205 La Laguna, Tenerife, Spain

[3]University of Bern, Center for Space and Habitability, Gesellschaftsstraße 6, CH-3012, Bern, Switzerland

[4]University of Geneva, Geneva Observatory, Chemin des Maillettes 51, CH-1290, Versoix, Switzerland

[5]Departamento de Astrofísica, Universidad de La Laguna, E-38206 La Laguna, Tenerife, Spain

[6]Department of Physics and Astronomy, University College London, Gower Street, WC1E 6BT London, UK

Accurate line lists are crucial for correctly modelling a variety of astrophysical phenomena, including stellar photospheres and the atmospheres of extra-solar planets. This paper presents a new line database TOTO for the main isotopologues of titanium oxide (TiO): $^{46}Ti^{16}O$, $^{47}Ti^{16}O$, $^{48}Ti^{16}O$, $^{49}Ti^{16}O$ and $^{50}Ti^{16}O$. $^{48}Ti^{16}O$ line list molecule containing transitions with wave-numbers up to 30,000 cm^{-1} i.e. long-wards of 0.33 μm. The TOTO line list includes all dipole-allowed transitions between 13 low-lying electronic states (X $^3\Delta$, A $^3\Phi$, B $^3\Pi$, C $^3\Delta$, E $^3\Pi$, a $^1\Delta$, b $^1\Pi$, c $^1\Phi$, d $^1\Sigma^+$, e $^1\Sigma^+$, f $^1\Delta$). *Ab initio* potential energy curves (PECs) are computed at the icMRCI level and combined with spin-orbit and other coupling curves. These PECs and couplings are iteratively refined to match known empirical energy levels. Accurate line intensities are generated using *ab initio* dipole moment curves. The TOTO line lists are appropriate for temperatures below 5000 K and contain 30 million transitions for $^{48}Ti^{16}O$; it is made available in electronic form via the CDS data centre and via www.exomol.com. Tests of the line lists show greatly improved agreement with observed spectra for objects such as M-dwarfs GJ 876 and GL 581.

Submitted to Monthly Notices of the Royal Astronomical Society
Available from https://arxiv.org/abs/1905.04587

Conference Papers

Latest advances in the abundance discrepancy problem in photoionized nebulæ

Jorge García-Rojas[1,2], *Roger Wesson*[3], *Henri M.J. Boffin*[4], *David Jones*[1,2], *Romano L.M. Corradi*[1,5], *César Esteban*[1,2] *and Pablo Rodríguez-Gil*[1,2]

[1]Instituto de Astrofísica de Canarias, Spain

[2]Dept. Astrophysics. Universidad de La Laguna, Spain

[3]University College London, UK

[4]European Southern Observatory, Germany

[5]Gran Telescopio Canarias, Spain

In this paper, we will focus on the advances made in the last few years regarding the abundance discrepancy problem in ionized nebulæ. We will show the importance of collecting deep, high-quality data of H II regions and planetary nebulæ taken with the most advanced instruments attached to the largest ground-based telescopes. We will also present a sketch of some new scenarios proposed to explain the abundance discrepancy.

Oral contribution, published in the "II workshop on Chemical abundances in gaseous nebulæ", Boletín Asociación Astronómica de Argentina (invited talk)
Available from https://arxiv.org/abs/1904.06763

Ionization correction factors for ionized nebulæ

Gloria Delgado Inglada[1], *Alexia Medina-Amayo*[1] *and Grażyna Stasińska*[2]

[1]Instituto de Astronomía, UNAM, México
[2]LUTH, Observatoire de Paris, CNRS

In this paper we discuss the calculation of chemical abundances in planetary nebulæ and H II regions through ionization correction factors (ICFs). We review the first ICFs proposed in the literature based on ionization potential similarities and we present the most recent ICFs derived from large sample of photo-ionization models. We also discuss some of the considerations that have to be kept in mind when using ICFs to compute the chemical composition of ionized nebulæ.

Oral contribution, published in the "II workshop on Chemical Abundances in Gaseous Nebulæ", held between 11–14 March 2019 in São José dos Campos, São Paulo, Brazil (invited talk)
Available from https://arxiv.org/abs/1905.01191

The peculiar outburst activity of the symbiotic binary AG Draconis

Rudolf Gális[1], *Jaroslav Merc*[1,2], *Laurits Leedjärv*[3], *Martin Vrašťák*[4] *and Sergey Karpov*[5,6,7]

[1]Institute of Physics, Faculty of Science, P.J. Šafárik University, Park Angelinum 9, 040 01 Košice, Slovak Republic
[2]Astronomical Institute, Faculty of Mathematics and Physics, Charles University, V. Holešovičkách 2, 180 00 Prague, Czech Republic
[3]Tartu Observatory, Faculty of Science and Technology, University of Tartu, Observatooriumi 1, Tõravere, 61602 Tartumaa, Estonia
[4]Variable Star and Exoplanet Section of Czech Astronomical Society, LSO (private observatory), 03401 Liptovská Štiavnica, Slovakia
[5]CEICO, Institute of Physics, Czech Academy of Sciences, Na Slovance 1999/2, 182 21 Prague, Czech Republic
[6]Special Astrophysical Observatory, Russian Academy of Sciences, Nizhniy Arkhyz 369167, Russia
[7]Institute of Physics, Kazan Federal University, 16a Kremlyovskaya St., Kazan 420008, Russia

AG Draconis is a strongly interacting binary system which manifests characteristic symbiotic activity of alternating quiescent and active stages. The latter ones consist of the series of individual outbursts repeating at about a one-year interval. After seven years of flat quiescence following the 2006–2008 major outbursts, in the late spring of 2015, the symbiotic system AG Dra started to become brighter again toward what appeared to be a new minor outburst. The current outburst activity of AG Dra was confirmed by the following three outbursts in April 2016, May 2017 and April 2018. The photometric and spectroscopic observations suggest that all these outbursts are of the hot type. Such behaviour is considerably peculiar in almost 130-year history of observing of this object, because the major outbursts at the beginning of active stages are typically cool ones. In the present work, the current peculiar activity of the symbiotic binary AG Dra is described in detail.

Oral contribution, published in the "50$^{\text{th}}$ Conference on Variable Stars Research", Brno, Czech Republic
Available from https://arxiv.org/abs/1905.04253
and from http://var.astro.cz/oejv/issues/oejv0197.pdf

The activity of the symbiotic binary Z Andromedæ and its latest outburst

Jaroslav Merc[1,2], *Rudolf Gális*[2], *Marek Wolf*[1], *Laurits Leedjärv*[3] *and François Teyssier*[4]

[1]Astronomical Institute, Faculty of Mathematics and Physics, Charles University, V. Holešovičkách 2, 180 00 Prague, Czech Republic
[2]Institute of Physics, Faculty of Science, P. J. Šafárik University, Park Angelinum 9, 040 01 Košice, Slovak Republic
[3]Tartu Observatory, Faculty of Science and Technology, University of Tartu, Observatooriumi 1, Tõravere, 61602 Tartumaa, Estonia
[4]Astronomical Ring for Amateur Spectroscopy Group

Z Andromedæ is a prototype of classical symbiotic variable stars. It is characterized by alternating of quiescent and

active stages, the later ones are accompanied by changes in both photometry and spectral characteristics of this object. The current activity of Z And began in 2000, and the last outburst was recorded at the turn of the years 2017 and 2018. An important source of information about the behaviour of this symbiotic binary during the ongoing active stage is photometric and spectroscopic observations obtained with small telescopes by amateur astronomers. In this paper, we present the results of analysis of these observations, with an emphasis on the significant similarity of the last outburst of Z And with the previous ones, during which jets from this symbiotic system were observed. The presented results point to the importance of long-term monitoring of symbiotic binaries.

Oral contribution, published in the "50$^{\text{th}}$ Conference on Variable Stars Research", Brno, Czech Republic
Available from https://arxiv.org/abs/1905.04251
and from http://var.astro.cz/oejv/issues/oejv0197.pdf

Review Papers

Astro2020 White Paper: Unlocking the secrets of late-stage stellar evolution through radio wavelength imaging

Lynn D. Matthews[1], Mark J. Claussen[2], Graham M. Harper[3], Karl M. Menten[4] and Stephen Ridgway[5]

[1]MIT Haystack Observatory, USA
[2]National Radio Astronomy Observatory, USA
[3]University of Colorado – Boulder, USA
[4]Max Planck Insitut für Radioastronomie, Germany
[5]National Optical Astronomy Observatory, USA

During the late phases of evolution, low-to-intermediate mass stars like our Sun undergo periods of extensive mass loss, returning up to 80% of their initial mass to the interstellar medium. This mass loss profoundly affects the stellar evolutionary history, and the resulting circumstellar ejecta are a primary source of dust and heavy element enrichment in the Galaxy. However, many details concerning the physics of late-stage stellar mass loss remain poorly understood, including the wind launching mechanism(s), the mass loss geometry and timescales, and the mass loss histories of stars of various initial masses. These uncertainties have implications not only for stellar astrophysics, but for fields ranging from star formation to extragalactic astronomy and cosmology. Observations at centimeter, millimeter, and submillimeter wavelengths that resolve the radio surfaces and extended atmospheres of evolved stars in space, time, and frequency are poised to provide groundbreaking new insights into these questions in the coming decade.

Published in Astro2020 Decadal Survey White Paper
Available from https://arxiv.org/abs/1903.05592

Molecular masers as probes of the dynamic atmospheres of dying stars

Lynn D. Matthews[1], Mark J. Claussen[2] and Graham M. Harper[3]

[1]MIT Haystack Observatory, USA
[2]National Radio Astronomy Observatory, USA
[3]University of Colorado – Boulder, USA

More than half of the dust and heavy element enrichment in galaxies originates from the winds and outflows of evolved, low-to-intermediate mass stars on the asymptotic giant branch (AGB). However, numerous details of the physics of late-stage stellar mass loss remain poorly understood, ranging from the wind launching mechanism(s) to the geometry and timescales of the mass loss. One of the major challenges to understanding AGB winds is that the AGB evolutionary phase is characterized by the interplay between highly complex and dynamic processes,

including radial pulsations, shocks, magnetic fields, opacity changes due to dust and molecule formation, and large-scale convective flows. Collectively, these phenomena lead to changes in the observed stellar properties on timescales of days to years. Probing the complex atmospheric physics of AGB stars therefore demands exquisite spatial resolution, coupled with temporal monitoring over both short and long timescales. Observations of the molecular maser lines that arise in the winds and outflows of AGB stars using very long baseline interferometry (VLBI) offer one of the most powerful tools available to measure the atmospheric dynamics, physical conditions, and magnetic fields with ultra-high spatial resolution (i.e., tens of μarcsec, corresponding to $\sim 0.002R_\star$ at $d \approx 150$ pc), coupled with the ability to track features and phenomena on timescales of days to years. Observational advances in the coming decade will enable contemporaneous observations of an unprecedented number of maser transitions spanning centimeter to submillimeter wavelengths. In evolved stars, observations of masers within the winds and outflows are poised to provide groundbreaking new insights into the atmospheric physics and mass-loss process.

Published in Astro2020 Decadal Survey White Paper
Available from https://arxiv.org/abs/1903.05602

Announcements

Lithium in the Universe: to Be to not to Be

This is the second announcement of the conference "Lithium in the Universe: to Be or not to Be", that will be held at the Observatory of Rome (Italy), from November 18 to 22, 2019.

The meeting will bring together experts from various fields to discuss the role played by lithium in several astrophysical contexts and to highlight the extraordinary character of this chemical species, as a tracer of the structure and evolution of stars, galaxies and the Universe.

The main topics of the meeting will be:

- Big Bang nucleosynthesis
- Nuclear reaction rates involving lithium and beryllium
- Physical processes in stellar interiors as traced by Li, Be, and B
- Hot bottom burning in massive AGB stars
- Lithium depletion in pre-MS stars and brown dwarfs
- Lithium and Beryllium in novæ
- Lithium in stellar clusters
- Galaxy evolution
- Lithium as tracer of the evolution of extra-galactic systems
- Lithium and the First stars
- Evolution in the disc and the bulge of the Milky Way
- Li abundance modelling

If interested, we kindly ask you to pre-register as soon as possible via the webpage of the conference, because the number of participants, owing to the limited capability of the conference room, will be restricted to 120. We won't be able to accept any registration once the afore-mentioned limit is reached.

Confirmed speakers:

- Jerome Bouvier (Observatoire de Grenoble, France)
- Sergio Cristallo (INAF – Osservatorio d'Abruzzo, Italy)
- Franca D'Antona (INAF – Osservatorio Astronomico di Roma, Italy)
- Barry Davids (Simon Fraser University, Canada)
- Brian Fields (University of Illinois, USA)
- Anibal García-Hernández (IAC Tenerife, Spain)
- Jordi José (Universitat Politècnica de Catalunya, Spain)
- Nadège Lagarde (France National centre for scientific research, France)
- Karin Lind (Max Planck Institute for Astronomy, Germany)
- Francesca Matteucci (Università di Trieste, Italy)
- Jorge Melendez (Universidade de São Paulo, Brasil)
- Paolo Molaro (INAF – Osservatorio di Trieste, Italy)
- Cyril Pitrou (IAP Paris, France)
- Rafael Rebolo (IAC Tenerife, Spain)
- Matthias Steffen (AIP Potsdam, Germany)
- Rodolfo Smiljanic (Nicolaus Copernicus Astronomical Centre, Poland)
- Aaron Steinhauer (State University of New York at Geneseo, USA)
- Bruce Twarog (University of Kansas, USA)

Important deadlines:

- Abstract submission: 25 June 2019
- Notification of speakers: 26 July 2019
- Payment of early registration fee: 15 September 2019
- Start of meeting: 18 November 2019

The venue will be the prestigious site of the Observatory of Rome, located in the town of Monte Porzio Catone. A daily bus service to reach and return from the Observatory will be available for the participants.

We will be able to offer support to a limited number of students. The students interested in this opportunity are kindly asked to apply within May 24, by sending a message to the email address of the conference, given below, with the object "request of support". The current position of the applier (i.e. 2$^{\rm nd}$ year PhD student), the affiliation and the supervisor of the research project must be indicated.

Contacts: e-mail: lithiumintheuniverse@gmail.com
Phone: +39-06/94286427

Fax: +39-06/94286406
webpage: https://lithiumintheuniverse.wixsite.com/lithium2019

Looking forward to seeing you in Rome!

See also https://lithiumintheuniverse.wixsite.com/lithium2019

RAS Specialist Discussion Meeting: Common envelope evolution and post-common-envelope systems

Registration is open for the RAS Specialist Discussion meeting "Common envelope evolution and post-common-envelope systems" to be held October 11$^{\text{th}}$ 2019 at the RAS headquarters in London (UK). The deadline for abstract submission is 31 August 2019 with further details available on the conference webpage https://commonenvelopes.space/

Description:

More than half of all solar-type stars exist in binary systems and a significant fraction of these are close enough to interact. In particular, the closest are expected to experience a common-envelope evolution whereby runaway, dynamically unstable, mass transfer leads to the entire system being engulfed by material lost from the envelope of one of the stars as it ascends the giant branch. The two stars then spiral in towards one another, shrinking the orbit and ejecting the envelope in the process.

The common envelope phase is critical for the formation of a wide variety of astrophysical phenomena, in particular transient phenomena like type Ia supernovæ and stellar mass gravitational wave sources, yet the exact physics of the process remains a mystery. Additionally, in the last few years, it has been shown that the common envelope phase may play an important role in explaining a long-standing problem of nebular astrophysics: the so-called abundance discrepancy problem.

This meeting aims to bring together the various communities, both theoretical and observational, working on different (post-)common-envelope phenomena in order to further our understanding of the process as a whole. This is particularly timely given that with the recent or impending arrival of various new observing facilities like Gaia, LSST and LIGO–VIRGO – heralded by some as the golden age of time-domain and transient astronomy.

See also https://commonenvelopes.space/