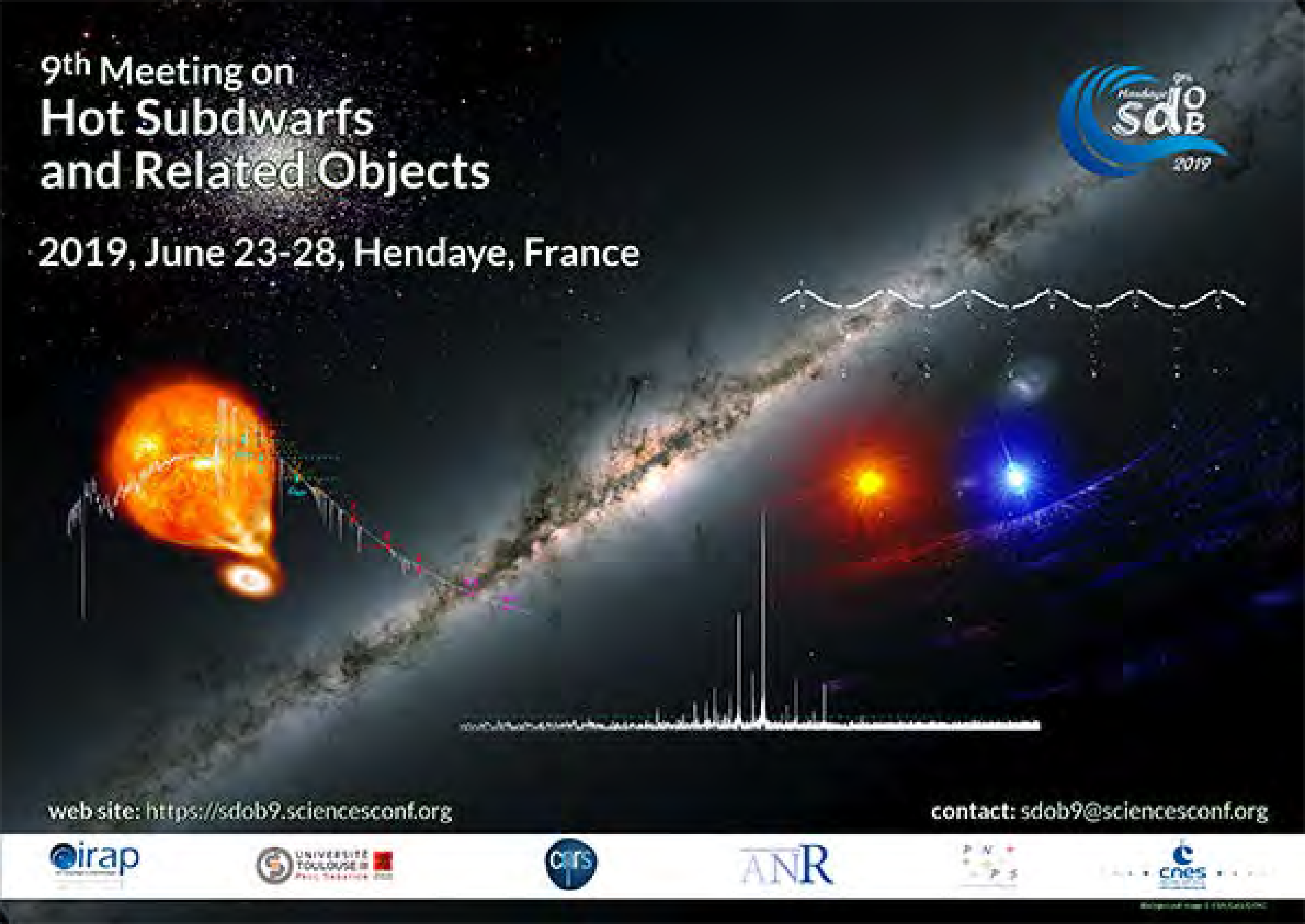
9th Meeting on
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Session 1 : Physiognomy of binary systems with hot subdwarfs or related objects

A Radial Velocity Survey of Candidate Variable Hot Subdwarfs from Gaia DR2

Nathan Grinalds * [1], Kyle Corcoran [2], Will Frondorf [1], Isaac Parker [1], David Vestal [1], Brad Barlow [1]

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Over the past few years, ESA's *Gaia* spacecraft has been obtaining astrometric measurements of more than 1 billion stars with unparalleled precision. The reported *Gaia* DR2 G magnitudes were determined by combining multiple brightness measurements, with photometric uncertainties being determined empirically. Thus, intrinsically variable sources could have anomalously large uncertainties for their given G magnitude. Leveraging this fact, we have identified more than 1,000 candidate variable hot subdwarfs in Gaia DR2. We have initiated a campaign with the CHIRON spectrograph on the CTIO 1.5-m telescope to monitor the radial velocities of all candidate variable hot subdwarfs with G $<$ 13 mag in the southern hemisphere. We have already identified several new rapid binaries. Here, we discuss the details of this survey and tentative results.

*Speaker

New Variable Hot Subdwarfs from the Evryscope

Brad Barlow * [1], Jeff Ratzloff [2], Kyle Corcoran [3], Thomas Kupfer [4], Veronika Schaffenroth [5]

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The Evryscope, built by astronomers at the University of North Carolina, was deployed at CTIO in May 2015 and represents the world's first full-sky gigapixel-scale telescope. With its 24 separate individual telescopes sharing a common mount, the system images an 8000 square degree field of view once every two minutes. The Evryscope has been building 1%-precision, high-cadence light curves for all accessible objects brighter than 16th magnitude since August 2016 and will continue to do so for the next couple of years. Light curves spanning several years are now available for more than 1000 bright candidate hot subdwarfs identified from Gaia DR2. Here I give an overview of the Evryscope's design and present the discovery of several new binaries showing reflection effect or ellipsoidal modulations.

*Speaker

Short period hot subdwarf variables

Thomas Kupfer * [1]

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The Zwicky Transient Facility (ZTF) is a next-generation optical synoptic survey with a 47 sqd. survey camera that builds on the experience and infrastructure of the Palomar Transient Factory and started science operations in March 2018. 40% of ZTF observing time is dedicated to two public surveys: one covering the entire Northern sky every three nights in g and r passbands and one visiting the Galactic Plane every night in g and r. In addition to the public Galactic Plane survey, ZTF has conducted a dedicated high-cadence survey of selected Galactic Plane fields to study the ultra-short variable sky. As part of this survey we have discovered a new class or radial mode hot subwarf pulsators as well as the most compact known hot subdwarf binary with an orbital period of 39min. In this talk, I will present an overview of the survey strategy and the population of photometric variable hot subdwarfs as well as describe the newly found pulsators and the binary in more detail.

*Speaker

Orbital and atmospheric parameters of two long period O-type hot subdwarf binaries

Francisco Molina * [1], Joris Vos [2]

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To date there are 23 long period binary systems that contain an sdB, whose orbitals parameters are known. We present the first orbital and atmospheric parameters from two long period O-type hot subdwarf systems: BD-11 162 and Feige 80. The long period hot subdwarfs binaries show bimodal behavior in terms of orbital period and eccentricity. The systems are representatives of the both groups, providing contrasting information. The CNO chemical abundances have been constrained for the main sequence stars. This provides an opportunity to link the obtained abundances with the accreted mass. The C/N ratio strongly differs in both systems pointing to differences in the mass-exchange features. From the data study, we provide a new perspective on the eccentricity topic that blurs the orbital bimodal behavior, despite their orbital and atmospheric differences, joining the systems in a relation that introduces the true governing factor of the eccentricity: the mass ratio. It opens a new path for theoretical studies on the basis of this conclusion.

*Speaker

Modeling wide hot subdwarf binaries with MESA

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The latest observations of wide hot subdwarf binaries with FGK companions have shown interesting correlations between the different orbital parameters. Next to the already known period – eccentricity relation a very strong correlation between orbital period and mass ratio was found. A preliminary analysis attributed this latter correlation to the stability of RLOF on the RGB. We have used an interaction model using the Kolb and Ritter L1 mass loss and a similar derivation to estimate the L3 mass loss. The resulting model does not have any free parameters left. In the first stage of this project, only circular orbits are considered. This interaction model in combination with the age-metalicity relation of our galaxy matches very well with the observed period – mass ratio relation. Furthermore the model predicts useful correlations between observed properties and the progenitor systems. Based on the MESA models we derived color magnitude diagrams and expected number densities for composite sdB and sdA binaries.

*Speaker

Hot subdwarfs with cool companions

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Post-common envelope binaries are highly important for resolving the poorly understood, very short-lived common envelope phase of stellar evolution. Hence, the observation of such systems over the whole parameter space will help to improve the comprehension of this phase, which is essential to understanding binary evolution. Hot subdwarfs (sdO/Bs) are the bare helium-burning cores of red giants which have lost almost all of their hydrogen envelopes. This mass loss is often triggered by common envelope interactions with close stellar companions. However, several close brown dwarf companions have been found, and interactions with even less massive objects like hot Jupiter planets have been proposed as a possible formation channel for the known single sdO/B stars. The on-going EREBOS project is dedicated to increase the number of analysed sdB binaries with cool companions. In optical surveys more than 170 new eclipsing systems have been found. They allow the accurate determination of the fundamental orbital and stellar parameters of each system. The quality of the space-based lightcurves provided by TESS that are released every month gives us the oportunity to also use non-eclipsing systems showing only the reflection effect to constrain the parameters. In this talk I will give a status report on the EREBOS project and our analysis of eclipsing and non-eclipsing hot subdwarfs with cool companions.

*Speaker

Photometric variability of binary hot subdwarf stars: from the ground to TESS

Ingrid Pelisoli * [1], Veronika Schaffenroth [1], Stephan Geier [1], Nicole Reindl [1], Joris Vos [1]

[1] University of Potsdam – Germany

Hot subdwarf stars are evolved, subluminous, helium-burning stars, most likely formed when red-giant stars lose their hydrogen envelope via interactions with close companions. They play an important role in our understanding of binary evolution, stellar atmospheres and interiors, and of the Galaxy itself. Hot subdwarfs that are still in a binary following their formation can show variability due to multiple effects, including eclipses, reflection, and ellipsoidal deformation. Modelling the light curves of such systems can provide constraints not only to the nature of the hot subdwarf star itself, but can also constrain the nature of the companion star, providing valuable input to evolutionary models of the formation of hot subdwarfs, which still have several open questions. Taking advantage of public ground surveys, we have searched for variability in known hot subdwarf stars. About a hundred new variables were identified, many of which were included in the target list for the Transiting Exoplanet Survey Satellite (TESS), which has been gathering light curves for thousands of nearby stars. In this talk, I will present results from our search for variable binary subdwarfs, from the identification of new variables in ground surveys, to the latest results obtained from TESS.

*Speaker

Variability in the light curves of Hot Subdwarfs

Tilaksingh Pawar * [1]

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The light curves of sdO and sdB stars quite often show periodic variability and features indicating close binarity. As a part of the ongoing EREBOS project we aim at obtaining and analysing the light curves of HW Vir type systems, consisting of a hot subdwarf and a cool companion. In another project we look for characteristic long-period pulsations in the light curves of He-sdO and He-sdOB stars caused by the theoretically predicted, but still not observationally confirmed, epsilon mechanism. Here we present preliminary results from observational campaigns conducted with the 2.15 m telescope at the CasLeo observatory in Argentina and the 2.2m telescope at Calar Alto in Spain.

*Speaker

The X-ray emission of the compact He-poor sdO star Feige 34

Nicola La Palombara * [1], Sandro Mereghetti [1], Paolo Esposito [1], Andrea Tiengo [2,1]

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We report on results obtained with the XMM-Newton observation of Feige 34, carried out in April 2018. This is the first spectroscopic X-ray observation of a compact and helium-poor hot subdwarf star. Its spectrum can be described with the sum of two thermal-plasma components with sub-solar abundances at temperatures of about 0.3 and 1.1 keV, respectively, while its flux of 3.4×10^{-14} erg/cm2/s (in the energy range 0.2-3 keV) implies an X-ray-to-bolometric flux ratio of about $10^{-6.5}$. These properties are similar to what is observed in early-type main-sequence stars, as well as in the luminous He-rich sdO stars previously observed with XMM-Newton. In these stars the X-ray emission is attributed to turbulence and shocks in the stellar wind. Therefore, the same phenomenon could explain the X-ray properties of Feige 34. However, it is not possible to reproduce the observed spectrum with a thermal-plasma model if the elemental abundances are fixed at the values obtained from the optical and UV spectroscopy. Moreover, we show that the X-ray luminosity and spectrum are consistent with those expected from a young main-sequence star of late spectral type. Therefore, we cannot exclude the possibility that the observed X-ray emission is due to the companion star of M0 spectral type, whose presence is suggested by the IR excess in the spectral energy distribution of Feige 34.

*Speaker

WD+He star systems and the formation of accretion-induced collapse events

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Accretion-induced collapse (AIC) events are a kind of electron-capture supernovae. It has been proposed that AIC events may be responsible for the formation of some troublesome NS systems that are difficult to form via type II core-collapse SNe, like low-/intermediate-mass X-ray binaries, low-/intermediate-mass binary pulsars, and millisecond binary pulsars. Generally, AIC events are thought to be formed from Oxygen-Neon white dwarfs (ONe WDs) when its mass approch to the Chandrasekhar mass limit. However, the progenitor models of AIC events are still poorly studied. In this talk, I will introduce our recent work on the formation of intermediate-mass binary pulsars from ONe WD+Helium star systems via the AIC processes, and the formation of AIC events from double WD merger model. I will also introduce an emerging channel for the formation of double WD systems from WD+Helium star systems, and discuss its influence on the formation of AIC events from the double WD merger model.

*Speaker

Recent progress in our understanding of Hen 2-428

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The nucleus of the planetary nebula Hen 2-428 is a short orbital period (4.2 h) spectroscopic binary, whose status as potential supernovae type Ia progenitor has raised some controversy in the literature. Here we report recent pitfalls and progress in our analysis of this unique system.

*Speaker

Session 2.1 : Hot subdwarf properties from binary studies

NY Vir System Revisited in the Light of New Data

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NY Virginis is a well-studied eclipsing binary system with a hot sdB component, in terms of its physical (Camurdan et al. 2012, Vuckovic et al. 2007), asteroseismological (Vuckovic et al. 2009), orbital (Qian et al. 2012 and Lee et al. 2014), convection and tidal properties (Preece et al. 2009). We have already provided a preliminary analysis of the orbital variations observed in the system back in the 8th Meeting on Hot subdwarf Stars and Related Objects (Baştürk & Esmer 2018). We have improved our analysis since then to fit different models with the Markov Chain Monte Carlo (MCMC) method, compare the results from those models, determine the best fitting model according to their likelihood ratios, and further discuss on the possibility of existence of circumbinary planets around NY Virgo system, accounting for the recently published and our own data sets acquired with the 1 m Turkish telescope T100, in TUBITAK National Observatory of Turkey. We also analyze the ultra-precise light curves from ULTRACAM on VLT published by Vuckovic et al. (2007, 2009), as well as the recent light curves obtained with the SOLARIS network telescopes (Kozlowski et al. 2017) with the most recent version of the Phoebe code, Phoebe-2 (Conroy et al. 2019) in an MCMC framework.

*Speaker

HW Vir: I'll be back!

Roy Østensen * [1], Maja Vučković [2], John Telting [3]

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Since its discovery 33 years ago, the eclipsing sdB+dM binary HW Vir has been the subject of numerous studies, photometrically and spectroscopically, and a recurring visitor at the sdOB meetings. Results presented at sdOB8 from K2 photometry revealed that light-travel time measurements indicated a tighter orbit than permitted if the primary is an EHB star. At the same meeting, spectroscopic results from Xshooter@VLT were presented, revealing the discovery of narrow emission lines from the secondary, but with orbital fits that again indicated a too low mass for the primary to be an EHB star. Here we reexamine the Xshooter data, applying the same methods that we used for AA Dor, revealing that the emission lines from the Ca-II triplet have a surprising origin, and when correctly interpreted, the spectroscopic evidence is perfectly consistent with a canonical EHB mass.

*Speaker

The pulsating sdB+dM binary 2M1938+4603 revisited combining asteroseismology and eclipse timing

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We present the analysis of 2M1938+4603 (KIC 9472174), a hot hybrid pulsating subdwarf B (sdB) star with a strong reflection effect. This analysis attempts to combine seismic modeling and investigation of variations in eclipse minima (O-C diagram) of this system, based on the full set (37 months) of available Kepler data. For asteroseismology, we focus on the 22 highest amplitude pulsation modes detected in the 2000-4500 μHz range (mostly p-modes), assuming the sdB star rotation period is locked to the orbital period (tidal synchronization). The seismic modeling provides in particular a constraint on the primary mass. We fit Lorentzian function to the detrended folded Kepler light curve for each individual eclipse to calculate eclipse minimum times, considering primary and secondary minima. We find an average delay 1.705 $\pm$ 0.111 s in the arrival times secondary eclipse relative to the expected time at phase 0.5, which is explained by the Romer delay. We also report the rate of orbital period changes P $\sim 3.442 \times 10^{-11}$ day.

*Speaker

The Romer delay in HW Vir type binaries

Andrzej Baran * [1]

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We will present a summary of our work on HW Vir type stars, particularly 2M1938+4603, HW Vir and AA Dor. Our main goal is to search for stellar pulsations in the primaries. As a by-product of the search we calculated the O-C and Romer delay for each target. Then, we used the Romer delay toward mass estimation. Even though, this approach has a weak point, we will show a consistent estimation, which can still be meaningful, and can contribute to distinguish between hot subdwarfs and post-red giant objects.

*Speaker

Session 2.2 : Hot subdwarf properties from atmospheric studies

The 3He anomaly and atmospheric helium stratification of sdB and BHB stars

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The 3He anomaly was first discovered in chemically peculiar B-type main sequence stars and attributed to atomic diffusion. The same phenomenon was discovered in the sdB star SB290 many years ago as well as in the prototypical BHB star Feige 86. In the meantime about a dozen sdB stars and a handful of BHB stars make up the class of evolved 3He stars. Along with the 3He anomaly several of these stars, in particular all BHB members show peculiar helium line profiles, which are explained by vertical stratification of the element in their atmosphere. We present the quantitative analysis of high resolution spectra to determine the 3He/4He abundance ratio and qualitatively describe the atmospheric stratification.

*Speaker

Fundamental Parameters of Hot Subdwarf Stars from Gaia Astrometry

David Schneider * [1], U. Heber [1], S. Geier [2], M. Latour [3], A. Irrgang [1]

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Asteroseismic modeling of pulsating hot subdwarf stars (sdBs/sdOs) and the investigation of eclipsing hot subdwarf binaries with low-mass or substellar companions (HW Vir systems) have contributed significantly to the list of sdBs/sdOs with known stellar masses. However, both methods are limited to the number of known pulsating sdBs and HW Vir systems. The fundamental stellar parameters (radius, luminosity, and mass) of individual sdBs/sdOs may also be determined spectrophotometrically, that is by a combination of quantitative spectral analysis and spectral energy distribution fitting to appropriate photometric data, provided that the distance (parallax) to the investigated object is precisely known. In the pre-*Gaia* era this was the case for just a handful of hot subdwarf stars. This has changed with the second *Gaia* data release, providing both the astrometry and the photometry for a large number of sdBs/sdOs. Now, no longer the parallax is the limiting factor for the spectrophotometric approach, but rather precise surface gravity determinations from quantitative spectral analyses are needed. We selected a sample of more than 50 bright and nearby hot subdwarfs of all spectral types (sdBs, sdOBs, He-poor and He-rich sdOs) and configurations (single and binary stars), for which reliable *Gaia* parallaxes, high-quality optical and near-infrared spectra as well as appropriate data from various different photometric systems are available. We focus on accurate quantitative spectral analyses, in particular on the determination of systematic uncertainties for effective temperatures and surface gravities. To achieve this, we use three different model approaches: local thermodynamic equilibrium (LTE), hybrid LTE/non-LTE (NLTE), and NLTE. In addition, two different analysis strategies round off the systematic analysis. The precise atmospheric parameters allow us to derive the radius, luminosity, and mass distribution for our sample and to compare them to the ones predicted from the main formation channels of hot subdwarf stars.

*Speaker

The chemical composition of heavy-metal hot subdwarfs: HZ44 and HD127493

Matti Dorsch * [1,2], Marilyn Latour [3], Ulrich Heber [2]

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A small group of intermediately He-enriched sdBs show extreme enhancement in heavy metals, but until recently only three stars of that type were known. The presence of strong Ge, Sn, and Pb lines in the UV spectrum of the iHe-sdO HZ44 suggests a strong enrichment of heavy elements, calling for a detailed analysis of its composition. We combine non-LTE model atmospheres with high-quality optical and (F)UV spectra of HZ44 and its hotter sibling HD127493 to determine their atmospheric parameters and metal abundance patterns. By collecting atomic data from literature we succeeded to determine abundances of 28 metals in HZ44, including the trans-iron elements Ga, Ge, As, Zr, Sn, and Pb. This makes it the best described hot subdwarf in terms of chemical composition. We also determined the abundance of 14 metals in HD127493, including Ga, Ge, and Pb. Heavy elements turn out to be overabundant by one to four orders of magnitude with respect to the Sun, with Zr and Pb among the most enriched elements. The resulting abundance patterns are discussed in the context of nucleosynthesis and diffusion processes.

*Speaker

Feige 46: a second pulsating intermediate He-sdOB and heavy-metal star ?

Marilyn Latour * [1], Matti Dorsch [2,3], Ulrich Heber [3]

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It was recently discovered that Feige 46 shows the same type of pulsations as observed in LS IV -14 116. Both stars are now defining a class of intermediate He-sdOB pulsators that display g-modes despite their relatively high effective temperatures ($T_{\rm eff} \sim$ 35-37 kK). The driving mechanism responsible for the pulsations still remains hypothetical: the two suggested models, the epsilon-mechanism in a He-burning shell and the kappa-mechanism through carbon and oxygen opacity-bumps, each have their own shortcomings. Besides their pulsations properties, the two stars also share kinematics properties typical of the galactic halo population. In addition, LS IV -14 116, is considered as the prototype of the "heavy-metal stars". Its optical spectrum features lines of yttrium, strontium and zirconium that have been associated with overabundances of about 4 dex with respect to the solar values. With the two stars being otherwise so similar, an obvious next step was to search for indications of heavy-metal enhancement in the available spectroscopic data of Feige 46. I will thus report on our spectroscopic analysis of the optical CASPEC and ultraviolet HST/GHRS spectra of the star.

*Speaker

The SALT survey of chemically peculiar subdwarfs

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A spectroscopic survey of hot subdwarfs previously reported as helium-rich is being carried out with the Southern Africa Large Telescope. This has led to the discovery of a star similar to V652 Her, and evidence that not all subdwarfs are subdwarfs. Other discoveries have included a lead-rich subdwarf, a metal-poor subdwarf, and more hot 'extreme helium star' analogues. Initially executed with the High-Resolution Spectrograph, the survey has been extended to use the Robert Stobie spectrograph, allowing the discovery phase to go deeper and faster. Immediate objectives include classifications and coarse analyses of 100 helium-rich subdwarfs, with fine analyses and other follow-up observations of chemically interesting stars. This presentation will introduce some of the emerging highlights from the initial phases of the survey.

*Speaker

Non-local Thermodynamic Equilibrium Model-Atmosphere Spectra of sdOB stars on Demand

Thomas Rauch * [1], Lisa Löbling [1]

[1] University Tübingen – Germany

For precise spectral analyses, local thermodynamical equilibirium (LTE) model atmospheres are only suited for stars with spectral type B or later. For all other stars, non-LTE modeling is mandatory. There are, however, NLTE effects in any star, at least towards higher energies and in high-resolution spectra. In the framework of a German Astrophysical Virtual Observatory (GAVO) project performed at Tübingen, the registered Virtual Observatory service TheoSSA (Theoretical Stellar Spectra Access, http://dc.g-vo.org/theossa) has been created. It provides on demand spectral energy distributions of hot, compact stars, e.g., sdO and sdOB stars. We show the capacity of TheoSSA and other GAVO services and tools developed at Tübingen during the past two decades.

*Speaker

NLTE spectral analysis of the intermediate helium-rich sdB CPD-20°1123

Lisa Löbling [1], Thomas Rauch * [1]

[1] University Tübingen – Germany

The majority of subluminous dwarf B (sdB) stars have a helium (He) poor surface, while a minority of about 10% are found to have extremely He-rich atmospheres. CPD-20°1123 belongs to the rare type of intermediate He-enriched sdBs (He = 45% by mass) showing peculiar surface abundances shaped by diffusion. Its effective temperature of 24000 K places this star at the high temperature edge until which it may be justified to use local thermodynamic equilibrium (LTE) model atmospheres for the spectral analysis. We performed a non-LTE analysis focusing on NLTE effects and present the first application of revised, elaborated model atoms of low ionization stages (II-IV) of light metals available via the Tübingen Model-Atom Database (TMAD).

*Speaker

Session 2.3 : Hot subdwarf properties from asteroseismic studies

Putting sdB star asteroseismology to the test with GAIA

Gilles Fontaine , Pierre Bergeron , Pierre Brassard , Stéphane Charpinet , Suzanna Randall * [1], Valerie Van Grootel , Marilyn Latour , Betsy Green

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Over the last two decades, we have completed quantitative asteroseismological studies for a total of 16 pulsating sdB stars, including 12 short-period variables and 4 slow g-mode oscillators. In our asteroseismological approach, we are sensitive to the surface gravity, effective temperature, total mass, as well as the internal composition of the star, and in some cases the rotation profile. These values may then be used to constrain different evolutionary scenarios. While the first two model parameters ($\log g$ and T_{eff}) can be independently estimated from spectroscopy in conjunction with model atmospheres and are used to constrain and/or test the asteroseismological result, the accuracy of the asteroseismic mass has so far been independently verified only for the rare case of the eclipsing binary pulsator PG 1336-018. With the advent of precise GAIA distance estimates we now have the opportunity to test the seismic masses – and the general validity of our approach – inferred for our full asteroseismic sample. We present the results of this test.

*Speaker

Asteroseismic modeling of hot subdwarfs observed by TESS

Valerie Van Grootel * [1], Stéphane Charpinet [2], Gilles Fontaine [3] , Pierre Brassard [3]

[1] Space Sciences, Technologies and Astrophysics Research Institute (STAR) – Université de Liège, Belgium
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[3] Département de Physique, Université de Montréal – Canada

The TESS space mission gathers since end 2018 high-quality photometric data for hundreds of hot subdwarfs. Among them, several dozens revealed to be pulsators, mainly with g-mode but also p-mode oscillations, as well as an hybrid one, TIC 169285097. In this talk, I will present the first attempts to model by asteroseismology some of the most promising TESS pulsators, using our classical forward modeling approach and our latest generation of hot subdwarf models.

*Speaker

Asteroseismology of the g-mode sdB pulsator TIC 278659026

Stéphane Charpinet * [1], Pierre Brassard [2], Gilles Fontaine [2], Valerie Van Grootel [3], Noemi Giammichele [1], Weikai Zong [4], The TASC WG8 Team

[1] Institut de recherche en astrophysique et planétologie (IRAP) – CNRS – Université Paul Sabatier (UPS) - Toulouse III, France
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[3] Université de Liège – Place du 20-Août, 7 4000 Liège, Belgium
[4] Beijing Normal University (BNU) – No. 19, XinJieKouWai St., HaiDian District,Beijing 100875, P. R. China, China

We present the asteroseismic analysis of TIC 278659026 (EC21494-7018), a bright sdB star discovered to be pulsating by the NASA/TESS instrument. The analysis is based on $\sim$ 28 day of nearly uninterrupted photometry revealing a rich g-mode pulsation spectrum, which is exploited, through a forward modelling optimization technique, to deliver constraints on TIC 278659026 fundamental parameters and internal structure. Among other derived properties, we find that this apparently single sdB star has a significantly lower mass ($M = 0.391 \pm 0.009\ M_{\odot}$) than typical hot B subdwarfs, suggesting that it could originate from a massive ($M \gtrsim 2\ M_{\odot}$) red giant that has not gone through the helium-core flash. We also obtain a relatively clear view of the internal chemical stratification inside TIC 278659026 which indicates that this star has burnt $\sim$ 43% (in mass) of its central helium and possesses a relatively large mixed core. This finding is in line with trends already uncovered for other g-mode sdB pulsators analyzed with asteroseismology. Finally, the amount of oxygen produced in the core is estimated, which could provide interesting constraints on the uncertain $C^{12}(\alpha,\gamma)O^{16}$ nuclear reaction rate.

*Speaker

Probing the convective cores of core-helium-burning giants using seismology

Sebastien Deheuvels * [1]

[1] IRAP – Observatoire Midi-Pyrénées – 14 Avenue Edouard Belin 31400 Toulouse, France

The internal structure of stars during the core-helium-burning (CHeB) phase remains very uncertain because the evolution of the convective core depends critically on the physical description of convective boundaries. Different treatments lead to widely different core sizes and durations of the CHeB phase. The detection of mixed modes in CHeB giants with CoRoT and Kepler data has given the exciting opportunity to test the extension of extra-mixing beyond the convective core of these stars. We here give an overview of the results obtained so far using the seismology of CHeB giants. In parallel, constraints are also currently obtained on the size of the helium-burning cores of sdB stars and on the CO cores of white dwarfs, which form from the ashes of the CHeB phase. Combining the seismology of red giants with the seismology of sdB stars and white dwarfs could thus yield new insights on the boundaries of convective cores during the CHeB phase.

*Speaker

Gauging convective cores in sdB stars with pulsating DA WDs

Francisco C. De Gerónimo [1], Tiara Battich * [1], Leandro G. Althaus [1], Alejandro H. Córsico [1]

[1] Instituto de Astrofísica de La Plata, Universidad Nacional de La Plata, CONICET – Argentina

Asteroseismology of white dwarfs stars can lead to a better understanding of the interior of these stars, and therefore, of the processes that build up the chemical profiles of these stars. In this work we explore how the pulsational properties of low mass DA white dwarfs models are altered by different assumptions of the He-burning convective core of hot subdwarf stars. Hot subdwarf stars do not evolve to the thermaly pulsing phase of the AGB. In this way, we avoid the uncertainties that the thermal pulses imprint on the chemical profile of the white dwarfs. We also compare our results with four low mass ($\sim 0.45\ M_{\odot}$) DAV white dwarfs present in the literature.

*Speaker

Asteroseismic signatures of the helium-core flash

Marcelo M. Miller Bertolami [1], Tiara Battich * [1], Alejandro H. Córsico [1], Joergen Christensen-Dalsgaard [2], Leandro G. Althaus [1]

[1] Instituto de Astrofísica de La Plata, Universidad Nacional de La Plata, CONICET – Argentina
[2] Stellar Astrophysics Centre [Aarhus] – Denmark

All evolved stars with masses $M \lesssim 2\ M_{\odot}$ undergo a helium(He)- core flash at the end of their first stage as a giant star. Although theoretically predicted more than 50 years ago, this core-flash phase has yet to be observationally probed. We show here that gravity modes (g modes) stochastically excited by the He-flash are able to reach the stellar surface, and induce periodic photometric variabilities in hot-subdwarf stars with amplitudes of the order of a few mmag. As such they can now be detected by space-based photometry with the Transiting Exoplanet Survey Satellite (TESS) in relatively bright stars (e.g. magnitudes IC $>$ 13). The range of predicted periods spans from a few thousand seconds to tens of thousand seconds, depending on the details of the excitation region. In addition, our models reproduce the pulsations observed in a couple of He-rich hot subdwarfs stars. These stars are, then, the most promising candidates to probe the He-core flash for the first time.

*Speaker

Asteroseismology of Kepler/K2 white dwarf stars

Barbara Castanheira * [1]

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Asteroseismology of white dwarfs observed by Kepler and K2 In this review, I will present the seismological analysis of all white dwarf stars observed by Kepler and K2. We compared the observed independent pulsation models with our model grid. Our models were calculated using the evolutionary code WDEC, where polytrope functions are cooled, and excited periods are computed. We have calculated millions of models, varying effective temperature, surface gravity, hydrogen mass layer, and helium mass layer. We have also computed self-consistent models using the evolutionary LPcode, where stars are evolved from the zero age main sequence to a certain temperature in the white dwarf cooling sequence. For this model grid, the only quantity that we have varied is the thickness of the hydrogen layer, since all the other parameters depend on the previous evolutionary phases. We will discuss the differences in varying the model grids, as well as the fitting techniques (eg. including the observed amplitudes as weights for the periods). Our goal is to estimate the true external uncertainties in asteroseismology of white dwarfs. Finally, besides the individual fits, we will discuss the ensemble results for white dwarfs. The better understanding of the internal structure of white dwarf stars places important constrains in low-mass stellar evolution.

*Speaker

Asteroseismology of Lambda Bootis stars

Benjamin Fernando * , Philipp Podsiadlowski [1], Stephen Justham [2]

[1] University of Oxford – United Kingdom
[2] University of Amsterdam – Netherlands

The Lambda Bootis stars are chemically peculiar, metal-deficient objects of unclear internal structure. They include the possible progenitor to SN1572 (Tycho's Supernova), also known as Tycho B, which if confirmed as the companion would be a valuable insight into the single-degenerate channel for Type Ia supernovae. We explore the possibility of using asteroseismology as a tool to constrain the internal configurations of such stars, using modelling to differentiate between the spectra which would be expected from a main sequence star versus a subdwarf-like star. We find a clear difference in the pulsation frequencies and separations of these two classes of star, even when the chemical peculiarity of the outer layers is taken into account.

*Speaker

Session 3.1 : Hot subdwarf populations and related objects

Gaia's treasure chest - The quest to compile an all-sky sample of hot subdwarfs

Stephan Geier * [1]

[1] University of Potsdam – Germany

Data Release 2 of the Gaia mission allowed us to start with the compilation of an all-sky sample of hot subluminous stars for the first time. Combining the Gaia data with data from ground-based spectroscopic and photometric surveys, we found 39800 candidates. Here I will report on the selection of the catalogue as well as its limitations and the progress we made to put better constraints on the candidate sample since the first version was released. I will also introduce a new project aiming at spectroscopic follow-up of a volume-limited 500 pc sample of hot subdwarfs.

*Speaker

Kinematics of sdB and sdOB stars from GAIA and SDSS data

Alexander Bastian * [1], Stephan Geier [1]

[1] Institute for Physics and Astronomy, University of Potsdam – Germany

We present the kinematic analysis of 279 sdB and sdOB stars from the GAIA Data Release 2 and compare that with a previous analysis using data from ground based proper motion surveys and the Sloan Digital Sky Survey DR 7. We use the GalPy python package to do an analysis of the stars' kinematic properties in order to separate them into thin disk, thick disk, and halo populations. We found that, using the significantly more precise proper motion measurements of GAIA DR2, the number of halo stars decreased from 78 in the previous analysis to 30, while the thin disk stars grew in number from four to 155.

*Speaker

Quantitative spectral analyses of blue horizontal branch stars

Steven Hämmerich * [1], Martin Altmann [2], Marcio Catelan [3], Andreas Irrgang [1], Ulrich Heber [1]

[1] Dr. Karl Remeis Observatory & ECAP, University Erlangen-Nürnberg – Germany
[2] Zentrum für Astronomie der Universität Heidelberg, ARI – Germany
[3] Pontificia Universidad Católica de Chile, Departamento de Astronomía y Astrofísica – Chile

Blue horizontal branch (BHB) stars in globular clusters (GC) show abundance anomalies and stratification of certain elements and many previous studies have focused on this population. However, these stars also exist in the galactic field, where they have not yet been analyzed as thoroughly as their globular cluster counterparts. In order to compare BHB stars in GCs and the field, and from that derive implications for stellar population and evolution models, it is crucial to have a sufficiently large sample of analyzed field BHB stars, which is the goal of this study. In order to determine the fundamental atmospheric parameters and abundances of many different elements the studied spectra, either ESO UVES spectra from a kinematically selected sample or archive data, were fitted with synthetic spectra, which were calculated using a hybrid LTE/non-LTE approach. The abundance analysis is based on NLTE-model atoms as well as LTE-line lists. To obtain a more complete picture, the spectral energy distributions and the kinematics of the program stars were analyzed as well. The sample can be divided into two groups, a cooler sample with temperatures ranging between 9,000 K and 11,000 K, and a hotter sample with temperatures between 14,000 K and 20,000 K. Hence the sample covers a wide range of different types of BHB stars.

*Speaker

Gaia Data Release 2 Catalogue of Extremely-low Mass White Dwarf Candidates

Ingrid Pelisoli * [1]

[1] University of Potsdam – Germany

Extremely-low mass white dwarf stars (ELMs) have masses lower than 0.30 solar masses and are born either as a result of a common-envelope phase or after a stable Roche-lobe overflow episode in a multiple system. The Universe is not old enough for ELMs to have formed through single-star evolution channels. As remnants of binary evolution, ELMs can shed light onto the poorly understood phase of common-envelope evolution and provide constraints to the physics of mass accretion. Most known ELMs will merge in less than a Hubble time, providing an important contribution to the signal to be detected by upcoming space-based gravitational wave detectors. There are currently less than 150 known ELMs; most were selected by colour, with a bias towards hot objects, in a magnitude-limited survey of the Northern hemisphere only. Recent theoretical models have predicted a much larger spacial density for ELMs than estimated observationally based on this limited sample. In order to perform meaningful comparisons with theoretical models and test their predictions, a larger and unbiased sample is required. In this work, we present a catalogue of ELM candidates selected from the second data release of Gaia (DR2). We have used predictions from theoretical models and analysed the properties of the known sample to map the space spanned by ELMs in the Gaia Hertzsprung-Russell diagram. Defining a set of colour cuts and quality flags, we have obtained a final sample of 1643 ELM candidates, out of which 1127 are within 1 kpc.

*Speaker

The mystery on the origin of extreme horizontal branch stars in globular clusters

Annalisa Calamida * [1]

[1] SPACE TELESCOPE SCIENCE INSTITUTE - AURA – United States

Extreme Horizontal Branch (EHB) stars have been observed in several Galactic Globular Clusters (GGCs) but their origin is still debated. Two main competing scenarios have been proposed: the hot-helium flasher scenario, where EHBs originate from stars which lost a significant amount of mass during the red-giant branch phase, possibly due to close binary interactions, and the helium-enhanced scenario, where the high temperatures of EHBs are attributed to a greatly enhanced star initial helium abundance. However, the confirmation of either formation scenarios has been hampered by the lack of observational contraints due to the faintness of EHBs and the crowdeness of GGC stellar fields. We recently launched the SHOTGLAS project (Spectroscopy of HOT GLobular cluster Aging Stars) with the aim of providing a comprehensive picture of this intriguing stellar population in terms of spectroscopic properties for all accessible GGCs hosting an EHB. In this talk I present results for w Cen, the most massive and peculiar GGC, for which we derived atmospheric parameters for 152 EHB stars. This constitutes the largest spectroscopic sample of EHBs ever analyzed in a GGC. We find that the majority of EHBs consists of sdOB stars that have roughly solar or super-solar atmospheric helium abundances. These stars do not have a significant counterpart population in the Galactic field. Moreover, by analyzing radial velocities, we find that the fraction of close binary EHBs in w Cen is less than 3%, in contrast with the large fraction of these binaries the field. We interpret these results as a difference in the population age and stellar environment in GGC and the Galactic field.

*Speaker

Session 3.2 : Origin and evolution, progenies and progenitors

Hot Subdwarf Stars from LAMOST DR5 and Gaia DR2

Zhanwen Han * [1], Yangping Luo [2], Peter Nemeth [3]

[1] Yunnan Observatories – China
[2] China West Normal University [Nanchong] – China
[3] Astroserver.org – Astroserver.org, Czech Republic

Combing Gaia DR2 with LAMOST DR5, we identified 924 hot subdwarf stars, among which 32 stars exhibit strong double-lined composite spectra. We measured the surface temperature T_{eff}, gravity $\log g$, helium abundance $y = n(\mathrm{He})/n(\mathrm{H})$, and radial velocities of 892 non-composite spectra hot subdwarf stars by fitting LAMOST observations with Tlusty/Synspec non-LTE synthetic spectra. We use LAMOST radial velocities, Gaia parallaxes and proper motions to calculate the 3D Galactic space motions and Galactic orbits of these hot subdwarf stars, and classify them as halo, thin disk or thick disk populations. By comparing to theoretical predictions, we tried to identify the formation channels of these hot subdwarfs.

*Speaker

Mining the future of low-mass, core-He-burning hot subdwarfs

JJ Hermes * [1]

[1] Boston University – United States

Mounting evidence — including space-based asteroseismology, double-lined spectroscopic binaries, and Roemer delay in eclipsing systems — suggests that many hot subdwarfs have masses well below the canonical mass of roughly 0.47 solar masses. It is possible for lower-mass, core-He-burning subdwarfs to descend from more massive ($>$ 2 solar-mass) progenitors that did not undergo a helium flash, so they can begin helium burning with core masses as low as 0.3 solar masses. In a few hundred million years, these low-mass hot subdwarfs will exhaust their core helium and evolve into carbon-oxygen-core white dwarfs with essentially the same mass. Thus, a population of $<$ 0.35 solar-mass white dwarfs with CO-cores might be distinguishable from helium-core ELM white dwarf counterparts by their substantially smaller radius. I will report on efforts to find the lowest-mass CO-core white dwarfs in the solar neighborhood with Gaia, with the goal of discovering and constraining the endpoints of low-mass hot subdwarfs.

*Speaker

Helium Stars, Heavy Metals, High Velocities and Explosions

Simon Jeffery * [1,2]

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[2] Armagh Observatory and Planetarium (AOP) – College Hill, Armagh BT61 9DG, United Kingdom

The term "hot subdwarf" refers to stars which are smaller than hydrogen-burning main-sequence stars and larger than white dwarfs. It includes stars in several different advanced stages of evolution. Most have surfaces severely depleted in either hydrogen or helium; some explanation exists for most of these. In between lie the rare "intermediate helium subdwarfs", which pose significant challenges, not least to explain their surface composition in terms of their surface physics and a coherent formation paradigm. Discovered in 2011, LS IV-14 116 became the first "heavy-metal subdwarf". This subgroup of intermediate helium subdwarfs shows extraordinary surface abundances of the heavy metals zirconium, yttrium, strontium, germanium and lead. Now numbering eleven stars, all heavy-metal subdwarfs appear to be on high-energy galactic orbits. Two pulsate in modes which, until now, were thought impossible. New theoretical results force us toward new questions and new ideas about the origin of these stars. This talk will focus on recent discoveries, it will attempt to define the challenges presented, and hopefully offer some possible solutions.

*Speaker

Helium star donors to thermonuclear supernovae

Tin Long Sunny Wong [1], Josiah Schwab * [1]

[1] University of California, Santa Cruz – United States

We perform binary evolution calculations of helium star - carbon-oxygen white dwarf binaries using the stellar evolution code MESA. We focus on 1-2 $M_{\odot}$ He stars that undergo thermal-timescale mass transfer. We survey the initial binary parameters (orbital period and He star mass) and determine which systems can evolve towards thermonuclear supernovae. Our time-dependent calculations resolve the stellar structures of both binary components, which allows accurate detection of the occurrence of off-center carbon ignitions. We find systems that successfully reach explosion generally have orbital periods of hours; it will be useful to understand the MW population of He star - WD binaries with these properties. We also describe the observational appearance of these systems near the time of explosion as they may be detectable in pre-explosion images of supernovae.

*Speaker

Effect of L3 mass loss on formation of sdB-MS binaries

Alexey Bobrick * [1], Joris Vos [2], Maja Vučković [3]

[1] Lund Observatory – Sweden
[2] Institut für Physik und Astrophysik [Potsdam] – Germany
[3] Valpariso – Chile

L3 mass loss can potentially affect the formation and properties of long- and short-period sdB-MS binaries. It takes place when the red giant progenitor of the sdB star overfills its Roche lobe sufficiently much to start losing parts of its atmosphere through the L3 point behind it. The material lost through the L3 point carries away a significant amount of specific angular momentum and this way may have a strong impact on the binary orbit. We report on the results of our ongoing detailed study of this process. We have constructed an analytical expression for L3 mass loss rates as a function of the radius of the donor, have implemented it in binary stellar evolution code MESA and also have verified the framework with hydrodynamic SPH simulations. I shall present the physics behind L3 mass loss, show examples of how it affects the formation of long- and short-period systems and discuss the effect in a broader context of common-envelope evolution.

*Speaker

Formation of hot subdwarf B stars with neutron star components

You Wu * [1], Xuefei Chen [1], Hailiang Chen [1], Zhenwei Li [1], Zhanwen Han [1]

[1] Yunnan Observatories, Chinese Academy of Sciences – China

Binary population synthesis predicts the existence of subdwarf B stars (sdBs) with neutron star (NS) or black hole (BH) companions. Several works have been dedicated to finding such systems, but none has been confirmed yet. We systematically investigate the formation of sdB+NS binaries, obtaining their population properties and shedding light on searching for such objects. SdB+NS binaries can be produced either from stable RLOF or from CE ejection. We show the characteristics of the produced sdB+NS systems, such as the mass of components, orbital period, the semi-amplitude of the radial velocity, and the spin of the NS component. Also, we obtain the properties of Galactic sdB+NS binaries, such as the number, the period distribution, the dependence on the age, the uncertainties of binary evolution and NS natal kicks, by combining binary population synthesis study. Most sdB+NS binaries are located in the Galactic disk with small RV semi-amplitude. SdB+NS binaries with large RV semi-amplitude are expected to be strong GWR sources and some could be resolved by LISA in future.

*Speaker

The Formation and Evolution of R Coronae Borealis Stars

Josiah Schwab * [1]

[1] University of California, Santa Cruz – United States

The merger of two white dwarfs is a promising channel for the production of low mass hydrogen deficient stars, including the single hot subdwarf stars and the R Coronae Borealis (RCB) stars. We present simulations of the evolution of RCB stars using the MESA stellar evolution code. We will discuss the effects of uncertain mass loss rates on the evolution of these objects, with a particular emphasis on the final masses that these objects have as they evolve to the blue and then eventually onto the WD cooling track.

*Speaker

Thermal Timescale Mass Transfer and the Growth of Helium White Dwarfs

Evan Bauer * [1], Lars Bildsten [1,2]

[1] Physics Department, UC Santa Barbara – United States
[2] Kavli Institute for Theoretical Physics, Santa Barbara – United States

Several hot subdwarfs have been discovered in short period binaries with M dwarf or brown dwarf companions. These are interpreted as post common envelope binaries (PCEB), and our work focuses on the possibility of young Helium white dwarfs as the hot subdwarfs in such systems. Binary evolution calculations using MESA predict that these binaries will undergo unstable mass transfer on the thermal timescale of the donor M dwarf. Accretion rates on these timescales exceed what a He white dwarf can stably burn at its surface, and so the envelope of the accretor will expand and drive net mass loss from the binary system. We find a range of parameters in such systems for which this net mass loss may stabilize further mass transfer that will then continue on the donor's thermal timescale. Shell burning can cause the He core of the accreting white dwarf to grow, perhaps even to the point that it approaches the mass needed to ignite core He burning. We propose that some observed binaries labeled as PCEB systems may in fact have already undergone this stage of evolution.

*Speaker

He-shell burning hot subdwarf B stars as candidates for blue large-amplitude pulsations

Xuefei Chen * [1]

[1] Yunnan Observatories – China

In the contribution, I will firstly give a brief analysis for the possibility of He-shell burning hot subdwarf stars as candidates for blue large-amplitude pulsations (BLAPs) and then discuss their formation channels from binary evolution. I will show that He-shell burning sdB stars with relatively thick H envelope may evolve through the location of BLAPs on the effective-temperature diagram and their pulsation period change rates are consistent with that of BLAPs. We suggest the BLAPs be produced from stable mass transfer, having long orbital periods ($\gtrsim$ 1000 d) with unseen MS companions.

*Speaker

BLAPS: the Possible Surviving Companions of Type Ia Supernovae

Xiangcun Meng * [1], Zhanwen Han [1], Philipp Podsiadlowski [2], Jiao Li [1]

[1] Yunnan Observatories, Chinese Academy of Sciences – China
[2] Department of Astronomy, Oxford University – United Kingdom

The debate on the progenitor nature of type Ia supernovae (SNe Ia) is still endless, although they are so important in many astrophysical fields. The single degenerate (SD) model predicts that there are many surviving companions in the Galaxy if the SD model contributes to a part of SNe Ia. The discovery of such surviving companion would be evidence to support the SD model. Recently, a new kind of mysterious variables are discovered, i.e. blue large-amplitude pulsators (BLAPs). We found that all the properties of the BLAPs may be reasonably reproduced by the surviving companions of SNe Ia. On the contrary, no any other channel may simultaneously explain all the properties of the BLAPs. Therefore, we suggest that the BLAPs are the surviving companions of SNe Ia, and the discovery of the BLAPs supports the SD model. Our model also predicts a new channel to form single hot subdwarf stars, consistent with a small group in the present hot-subdwarf-star sample.

*Speaker

Session 4 : Hot subdwarfs and their pulsations

A Pulsation Mechanism for He-rich sdOBV stars

Marcelo Miller Bertolami * [1], Tiara Battich [1], Alejandro Córsico [1], Jørgen Christensen-Dalsgaard [2], Leandro Althaus [1]

[1] Instituto de Astrofísica de La Plata – Argentina
[2] Stellar Astrophysics Centre – Denmark

We will discuss the possibility that the observed multiperiodic photometric variability in He-rich sdOBV stars is caused by stochastically excited g-modes driven by unstable He burning. We will show that such mechanism is able to excite pulsations with periods and amplitudes similar to those observed in LS IV-14° 116 and Feige 46.

*Speaker

Asteroseismology of Tidally Distorted sdB Stars

Holly Preece * [1]

[1] Institute of Astronomy, University of Cambridge & Armagh Observatory and Planetarium – United Kingdom

A subset of the hot subdwarf stars are intrinsic variables with pulsations which can be observed with asteroseismology. Asteroseismology often relies on the assumption of spherical symmetry. Many of the observed sdB systems are also single lined spectroscopic binaries in close orbits. Whether the stars are tidally synchronized is under debate. However the closest of these systems certainly experience significant tidal interactions. These systems are sufficiently distorted by tidal interactions to break spherical symmetry. We investigate the significance of the tidal interactions on the observable pulsation frequencies of detailed numerical sdB stars. We develop a method for estimating the perturbations to the observed eigenfrequencies owing to the tides. We compare our method to previous work in the field, mostly involving polytrope calculations, and then apply the method to detailed numerical models of sdB stars. We consider the model dependence of the results and comment upon which systems are most affected by tidal interactions.

*Speaker

Musical Orchestra of sub dwarf B stars in NGC6791

Sachu Sanjayan * [1,2], Andrzej Baran [1], Jakub Ostrowski [1], Sumanta Sahoo

[1] Pedagogical University of Krakow – Poland
[2] Copernicus Astronomical Center of the Polish Academy of Sciences – Poland

We analyzed Kepler super apertures LC data of the open cluster NGC6791 to search for new pulsating sdB stars. We found a sample of many pulsating and binary stars, among which three of them are sdBV stars KIC2569576 (B3), KIC2437937 (B5) and KIC2438324 (B4). These stars were known before, though we extended the data coverage detecting more frequencies and features in periodograms, like new multiplets, extended period spacing sequences and candidates for trapped modes. We will show our results using the usual tools, like the KS test, echelle diagrams and reduce period diagrams. Our result will surely help calculating well constrained evolutionary models of these stars.

*Speaker

On a mode geometry in a sample of subdwarf B stars observed by TESS

Sumanta Sahoo * [1,2], Andrzej Baran [3,2], Sachu Sanjayan [1,2], Jakub Ostrowski [2]

[1] Copernicus Astronomical Center of the Polish Academy of Sciences – Poland
[2] Pedagogical University of Krakow – Poland
[3] Mt. Suhora Observatory – Poland

We present our results of a mode identification in several pulsating subdwarf B (sdB) stars observed by TESS. Most of the stars we analysed were monitored with the short cadence data, while only one with the long cadence data. All stars in our sample are rich g-mode pulsators. We found no multiplets and we based our identification solely on the asymptotic period spacing using KS tests and Echelle diagrams. We also found many candidates for trapped modes.The mode identification will surely help us to better constrain pulsation models of sdB stars.

*Speaker

Gravity (g) mode pulsators from the TESS mission

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We have analyzed a total of 615 hot subdwarfs and candidates that have been observed in the first 8 sectors of the TESS space mission with a cadence of 2-min and found periodicities in about 50 hot subdwarfs out of which 34 are new pulsators. We have analyzed 14 g-mode hot subdwarf B pulsators (sdBVg) extracting about 270 frequencies in total. Since these are g-mode pulsators, we have searched for asymptotic period spacings and found that 12 out of 14 sdBVg stars show clear sequences of dipole (l=1) and/or quadrupole (l=2) modes. We carried out Kolmogorov-Smirnov and Inverse Variance tests to quantify the significance of identified modal degrees. While 11 stars show a dipole mode sequence with an average spacing of about 260 seconds, one star shows pure quadrupole sequence with an average spacing of 160 seconds. In total, we identified more than 130 dipole modes and more than 30 quadrupole modes in 12 sdBVg stars observed in first 8 sectors of TESS mission. We have also searched for multiplet structures (frequency splittings), however, no multiplets of either l=1 nor l= 2 have been detected.

*Speaker

Kepler view on sdB pulsators: amplitude and frequency variations of oscillation modes

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With the help of Kepler photometry, frequency of close oscillation modes, such as rotational multiplets, can be well resolved and their amplitude can be precisely measured. We thus have the first opportunity to examine the variability of oscillation modes in pulsating sdB stars. Since 2013, we have obtained some interesting results in this field: 1) we observed that oscillation modes generally exhibit amplitude and frequency modulations (AM/FM) in many sdB pulsators; 2) coherent AM/FM occur on rotational multiplets in sdB, which can be the clear-cut signature of nonlinear resonant mode interactions; 3) the modulation patterns can be very helpful for identifying modes prior to seismic modelling; and 4) frequency modulations can perturb accurate measurements of secular (evolutionary) or regular (due to the presence of a stellar or planetary companion) period changes in the pulsations over long time baselines. We also discuss the difficulties of measuring precise instrinsic AM/FMs even with up to four years of continuous photometry. Such phenomena can also thoroughly be studied in many other types of pulsating stars spanning the whole HR diagram, using the photometry available from the Kepler legacy and from the ongoing TESS mission.

*Speaker

Pulsation Timing Analysis for a Pulsating Subdwarf B star, EC 05217-3914

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EC 05217-3914 is a pulsating subdwarf B (sdB) star and three pulsation frequencies (7.29 mHz, 7.04 mHz, and 6.35 mHz) are known so far. The pulsation periods of sdB variables are usually stable, and therefore they are good chronometers. A star's position in space may wobble due to the gravitational perturbations of a companion. From an observer's point of view, the light from the pulsating star is periodically delayed when it is on the far side of its orbit and advanced on the near side. Changes in the pulse arrival times are detected using the pulsation timing method. This star has been monitored by 0.6 – 1.0 m telescopes since the late 1990s. Using $\sim$ 20 years of photometry data, the pulsation timing analysis was performed to search the existence of a companion to the sdB star and to constrain sdB star evolutional scenarios. Although the signal to noise ratio of the second and third largest amplitude pulsations was too low to analyze, the timing of the largest amplitude pulsation shows periodic variation, which may be due to the existence of a companion. This presentation shows the result of the analysis and the existence of a possible companion.

*Speaker

Theoretical pulsation spectra for the 4th generation models of hot subdwarf stars

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In this poster, we investigate the theoretical pulsation spectra of hot subdwarfs. We used the 4th generation (4G) of our static, parameterized, models of hot subdwarfs and our usual adiabatic pulsation code Pulse. These 4G models include a more detailed description of the envelope (double layer structure with H and He), a more detailed description of the chemical transitions, as well as the account of the possible C-pollution of the mantle encountered during the He-flash. We computed the p-modes and g-modes spectra from 50 s to 10,000 s obtained by varying one by one the parameter of the 4G models, in order to highlight (1) the general behavior of pulsation modes in hot subdwarfs (adimensional p-modes, trapped g-modes, mixed modes and avoided crossings), and (2) the relative importance of each parameter on the theoretical pulsation spectra.

*Speaker

Session 5 : Evolved compact stars as laboratories for stellar physics

Recent results on the peculiar sdO binary HD49798

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HD49798 is the only confirmed X-ray binary composed of a hot O-type subdwarf star and a compact object. The latter is either a neutron star or a white dwarf, as testified by its spin period of 13.2 s measured in X-rays. Thanks to the presence of regular X-ray pulsations and an estimate of the system inclination from the eclipse duration, it has been possible to establish that the compact object has a mass of 1.28 +/- 0.05 solar masses Although this does not allow us to discriminate between a neutron star and a massive white dwarf, the precise distance of 508 pc measured with Gaia strongly supports the white dwarf hypothesis. We recently found that the compact companion of HD 49798 has been steadily spinning up at a rate of 2×10^{-15} s/s for more than 20 years. The mass accretion rate, inferred from the X-ray luminosity and the most recent models of the wind from HD 49798, is too small to cause such a rapid spin-up in a white dwarf. A possible solution is that the spin-up is caused by the decreasing moment of inertia of a massive white dwarf with an age of only $\sim$ 2 Myrs, still in the early contracting phase. Such an age is consistent with the evolutionary history of this system. If confirmed, this would be the first observational evidence for a WD contraction, predicted by theory but never observed before (most known WD are too old and/or in accreting binary systems where the effects of a high accretion rate dominate the spin-period variations). Independent on the nature of the compact object, the study of the accretion-powered X-ray emission in this system offers the possibility to investigate the properties of the weak stellar wind of HD 49798. I will discuss the result of the most recent X-observations and the prospects for future studies of this, so far, unique system.

*Speaker

S-process nucleosynthesis during the formation of He-rich hot subdwarfs

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We explore the synthesis of s-process elements during the formation of He-rich sdO/B and the emergence of these elements at the surface, with a recently developed post-processing code of detailed stellar nucleosynthesis. The study of the detailed nucleosynthesis on the He-rich sdO/B can shed light on the formation history of these objects, that is not well understood yet. In this first study, we focus on the hot-flasher scenario. We present here preliminary results.

*Speaker

Modern evolutionary modelling of sdB stars using the MESA code

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Subdwarf B (sdB) stars present unique opportunities for testing the properties of evolutionary models during the core helium burning phase. The number of discovered pulsating sdB stars is growing rapidly and creates demand for new, improved evolutionary models capable of tackling the long-standing problems concerning helium burning, such as occurrences of breathing pulses or uncertainties related to convective core growth. Our area of interest here is studying the properties of recent sdB star models, calculated by using the latest version of MESA - the state-of-the-art stellar evolution code, followed by presenting the updated basic properties of these stars. We also compare models with the traditional approach to determining boundaries of convective zones with the models that utilise updated algorithms available in MESA: predictive mixing and the convective premixing scheme.

*Speaker

Atomic Diffusion in Chemically Peculiar Hot Subdwarfs

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The number of chemically peculiar hot subdwarfs showing extreme heavy metal overabundances has reached a population of ten objects. These stars show super-solar abundances of exotic elements including lead, zirconium and germanium. The origin of these chemical peculiarities remain unclear. Stratification of the atmosphere as a result of atomic diffusion is a plausible explanation. Radiative levitation is the process whereby ions experience an outward force due to the flux of radiation from the star, and this behaviour is dependent on the atomic structure and opacity of a particular ion. Competition with the inward force of gravity leads to ions accumulating in regions of the star where the two forces are balanced. We outline experiments carried out with the Armagh stellar atmosphere codes to study the effects of stratification and atomic diffusion in the atmosphere of hot subdwarfs. Comparing synthetic spectra from these models with observations provides us with insight into the stratification structure of the atmosphere.

*Speaker

Super Metal-Rich Hot Subdwarfs as Tools for Atomic Physics

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Some hot subdwarfs are chemically peculiar, exhibiting extreme metal overabundances. Besides this phenomenon, they are, thus, ideal laboratories to precisely measure atomic properties like oscillator strengths. We present a preliminary spectral analysis of such subdwarfs and evaluate the quality of available atomic data for iron-group elements (Ca - Ni).

*Speaker

The formation of a CONe white dwarf through super AGB evolution

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For a star with the initial mass in the range of about $8 \sim 10\ M_{\odot}$, carbon can be ignited off-center in the central part of the star to produce a CONe white dwarf, if the stellar envelope is removed quickly after the carbon-burning process. The structure of the CONe white dwarf sensitively depends on the treatment of the convective mixing during the carbon-burning process. If the convective mixing is restricted strictly in the Schwarzschild boundary, the carbon-burning process in a convective shell can propagate to the stellar center, resulting in a white dwarf with an ONe core surrounded by a CO envelope (Siess 2006). If the convective overshooting is considered below the bottom of the convective shell, however, the carbon-burning process do not reach the stellar center, and a white dwarf is to be formed with a CO core surrounded by a thick ONe envelope (Denissenkov et al. 2015). By use of a more reliable theory of stellar convection, the k-w model (Li 2012, 2017), we investigated the overshooting beyond both boundaries of the convective shell, and found that the overshooting can shortly extend to the stellar center at first and quickly subside to the Schwarzschild boundary. As a result, the carbon-burning process also do not reach the stellar center, resulting in the formation of a CONe white dwarf with a CONe core surrounded by a ONe envelope.

*Speaker