Contents

Scientific Program: Talks	3
Abstracts: Talks	9
Abstracts: Posters	105
Participants	175
Code of Conduct	179

1 Scientific Program: Talks

The individual time slots for talks are 12 minutes plus 3 minutes for discussion.
Talks marked with (V) will be given virtually.
All speakers have to make sure that their talk is on our workshop computer at least 30 minutes before the respective session. Please contact malyshev@astro.uni.tuebingen.de.

Monday, August 15, 2022

09:00	Werner	Welcome & Opening
		Chair: Hermes
		T1: White dwarf samples, surveys, and luminosity functions
09:15	Jordan	White dwarfs in Gaia DR1, DR2, EDR3, and DR3
09:30	Barstow	White dwarfs in Gaia DR3
09:45	Mander	Synthetic photometry and the white dwarf luminosity function in Gaia DR3
10:00	Vani	Properties of White Dwarfs in the JJ model based on Gaia EDR3
10:15	O'Brien	Completing the 40 pc spectroscopic sample of Gaia white dwarfs
10:30		coffee & posters
11:15	Bagnulo	A spectropolarimetric survey of white dwarfs in the local 20pc volume
11:30	Vincent	A neural network-based algorithm for fast classification and analysis of large samples of white dwarf stars
11:45	Caiazzo	A survey of white dwarf merger remnants with ZTF
12:00	Castanheira	White Dwarfs in the HETDEX survey
12:15	Kosakowski	The ELM Survey South
12:30	LOC	Announcements
12:35		lunch
		Chair: Pelisoli
14:15	Cukanovaite	*Local stellar formation history from the 40pc white dwarf sample (V)*
14:30	Lam	Star Formation History – The Story As Told By The Galactic White Dwarf Luminosity Functions
14:45	Raddi	White dwarfs and the Galactic chemodynamics
15:00	Zakamska	A modern look at the white dwarf equation of state and at the binary white dwarf population
15:15	Parker	CSPN in the HASH database - Investigations and Insights
15:30		coffee & posters
		T2: SN Ia connection
16:15	Ugalino	Three-dimensional simulations of turbulently-driven deflagration-to-detonation transition in near-Chandrasekhar type Ia supernovae
16:30	Wong	He Flash Due to Mass Transfer from High-entropy He WDs
16:45	Burmester	AREPO White Dwarf merger simulations resulting in edge-lit detonation and run-away hypervelocity companion
17:00	Pritzkuleit	Hyperrunaway hot subdwarfs from supernovae type Ia
		T3: White dwarfs with planetary systems
17:15	Cheng	Planet candidates around massive white dwarfs
17:30	Wangnok	Investigation of the circumbinary planet in a polar CV DP Leo

Tuesday, August 16, 2022

		Chair: El-Badry
		T3: White dwarfs with planetary systems
09:00	Vanderbosch	Discovery and Characterization of Transiting Planetary Debris Systems with Gaia and ZTF
09:15	Guidry	Characterizing the Orbital Periods of Transiting Planetary Debris around White Dwarfs
09:30	Gentile Fusillo	White dwarfs and gas discs: the good, the bad, and the weird
09:45	Rogers	Using polluted white dwarfs to understand exoplanetary material
10:00	Elms	Spectral analysis of ultra-cool white dwarfs polluted by planetary debris
10:15	Kaiser	The Origin of Lithium Enhancement in Polluted White Dwarfs
10:30		coffee & posters
11:15	Badenas Agusti	Spectroscopic Characterization of Helium-Dominated Polluted White Dwarfs with Machine Learning
11:30	Cunningham	A white dwarf accreting planetary material determined from X-ray observations
11:45	Maldonado	Understanding the origin of metal pollution in white dwarf atmospheres through dynamical evolution of planetary systems
12:00	Okuya	Modeling of Accretion Disks Originating from Disrupted Rocky/Icy Planetary Bodies around White Dwarfs
12:15	Swan	Infrared variation at dusty systems
		T4: Atmospheres: composition & evolution
12:30	Dunlap	Flux Calibration and Balmer Line Shapes
12:45		lunch
		Chair: Pala
14:15	Tremblay	Improved Simulations of Stark Broadened Helium Line Profiles for DB White Dwarfs
14:30	Gamrath	Systematic Calculations of oscillator strengths of intermediatly ionised trans-iron elements for the spectral analysis of hot white dwarfs
14:45	Landstorfer	Super Metal-Rich Pre-White Dwarfs as High-Precision Atomic-Physics Laboratories
15:00	Wajid	New Transition Probabilities for Trans-Iron Elements: Zn IV
15:15	Izquierdo	Systematic uncertainties in the characterisation of He-dominated metal-polluted white dwarfs
15:30		coffee & posters
16:15	Bédard	A detailed modeling of the DO-to-DA spectral evolution
16:30	Filiz	Spectral analysis of hot DA- and DAO-type white dwarfs
16:45	Sahu	HST/COS Ultra-Violet high-resolution spectroscopic survey of DA White Dwarfs
17:00	López-Sanjuan	Spectral evolution and calcium white dwarfs in J-PLUS
17:15	Landstreet	Rotation periods and surface magnetic field structures of young weak-field magnetic white dwarfs
17:30	Amorim	Magnetic White Dwarfs rich in Hydrogen

Wednesday, August 17, 2022

		Chair: Dunlap
		T4: Atmospheres: composition & evolution
09:00	Hardy	Spectrophotometric analysis of hydrogen rich magnetic white dwarf stars
09:15	Moss	Spectroscopic Variability of Magnetic White Dwarfs
09:30	Reindl	Update on UHE white dwarfs
09:45	Walters	DAHe stars have active chromospheres
10:00	Hermes	Emerging thoughts on the new class of DAHe white dwarfs
10:15	Stopkowicz	Prediction and assignment of spectra from strongly magnetized White Dwarf stars using high-accuracy quantum chemistry
10:30		coffee & posters
11:15	Farihi	Evidence that all DQ stars are binary / merger products
11:30	Kowalski	Consistent model fits to the complete spectra of cool DQ/DQp stars
11:45	Miller	Massive White Dwarfs From Nearby Young Clusters
		T5: Pulsating and variable white dwarfs
12:00	Antunes Amaral	Search for new variable Extremely-low mass white dwarf stars
12:15	Calcaferro	*Exploring the internal rotation of the extremely low-mass white-dwarf star GD 278 with TESS asteroseismology (V)*
12:30	Boston	*Ensemble asteroseismology of blue-edge ZZ Cetis using THRAIN, the mighty white dwarf code (V)*
12:45		lunch
		Chair: Battich
14:15	Romero	Pulsating White dwarfs with hydrogen-rich atmospheres
14:30	Sowicka	GW Vir instability strip in the light of new observations of PG 1159 stars
14:45	Uzundag	Pulsating hydrogen-deficient white dwarfs and pre-white dwarfs observed with TESS: Discovery of new GW Vir stars
17:00		busses start to conference dinner

Thursday, August 18, 2022

		Chair: Raddi
		T5: Pulsating and variable white dwarfs
09:00	Kumar	Seismology of accreting white dwarfs
		T6: Structure, stellar evolution, fundamental physics
09:15	Bauer	MESA Models of WD Cooling with C/O Phase Separation
09:30	Camisassa	Ultra-massive white dwarf models
09:45	Jeffery	Improving Ages of Individual White Dwarfs
10:00	Battich	Structure and evolution of massive white dwarfs in general relativity
10:15	Perot	Tidal deformability of crystallized white dwarfs in full general relativity
10:30		coffee & posters
11:15	Blouin	Recent progress on the modelling of crystallizing white dwarfs
11:30	Ginzburg	*Crystallization dynamos: slow convection and fast rotation (V)*
11:45	Montgomery	Improving the Physics of Mixing During Phase Separation in Crystallizing White Dwarf Stars
12:00	Korkov	New Evolutionary Channel of Magnetic White Dwarfs?
12:15	Schreiber	The origin and evolution of strong magnetic fields in white dwarfs
		T7: White dwarfs in binaries, cataclysmic variables
12:30	Parsons	The White Dwarf Binary Pathways Survey
12:45		lunch
		Chair: Reindl
14:15	Torres	A population synthesis study of the Gaia resolved white dwarf binary population
14:30	Korol	*Double white dwarf separation distribution: astrometric evidence from GAIA for a gap at 1 AU (V)*
14.45	Hollands	Measuring the initial-final mass relation using wide binaries
15:00	Barrientos	Improved Constraints on the Initial-to-Final Mass Relation of White Dwarfs using Wide Binaries
15:15	Heintz	Testing White Dwarf Age Estimates using Wide Double White Dwarf Binaries from Gaia EDR3
15:30		coffee & posters
16:15	Rajamuthukumar	White dwarf interactions in triple star systems
16:30	Rebassa-Mansergas	An old triple system with an inner brown dwarf-white dwarf binary and an outer white dwarf companion
16:45	Chickles	Searching for eclipsing double white dwarfs in TESS 200s full frame images
17:00	Lagos	Evidence for a bi-modal distribution of post mass transfer systems?
17:15	Brown	High-speed follow-up of eclipsing WD+dM binaries from ZTF
17:30	Caiazzo	A survey of white dwarf merger remnants with ZTF

Friday, August 19, 2022

		Chair: Schreiber
		T7: White dwarfs in binaries, cataclysmic variables
09:00	Schaffenroth	A bright, hot white dwarf with an M dwarf companion showing a large reflection effect
09:15	Hallakoun	*An ultra-hot irradiated likely brown dwarf orbiting a white dwarf (V)*
09:30	van Roestel	Uncovering the population of close white dwarf binaries using eclipses
09:45	Pala	Evolution of accreting white dwarfs from HST and Gaia
10:00	Green	Eclipse Timing of AM CVn Binary Stars
10:15	Munday	Over 20 years of the shortest-period binary star system HM Cancri: orbital decay and MESA evolution – AM CVn
10:30		coffee & posters
11:15	Littlefair	Angular Momentum Loss in accreting WD binaries
11:30	El-Badry	A ZTF survey for evolved cataclysmic variables turning into extremely low-mass white dwarfs
11:45	Muñoz Giraldo	X-ray orbital modulation of a candidate period bounce cataclysmic variable
12:00	Suleimanov	Hard X-ray luminosity function of Cataclysmic Variables in Gaia era
12:15	Neustroev	On the determination of fundamental parameters of accreting white dwarfs
12:30	Shen	Binary Interaction Dominates Mass Loss in Classical Novae
12:45		lunch
		Chair: Romero
14:15	Rawat	Unveiling the nature of two intermediate polars: V902 Mon and SWIFT J0746.3-1608
14:30	Ramirez	A study of TCP J2104, a highly evolved Cataclysmic Variable
14:45	Pelisoli	Searching for AR Sco 2.0: are other white dwarf pulsars out there?
15:00	Poggiani	*Post-outburst Spectroscopic Investigation of Northern Novae (V)*
15.15	Toloza	The C/N ratio from FUV spectroscopy as a constraint upon the past evolution of HS0218+3229
15:30	Werner	Closing

2 Abstracts: Talks

Date and time of the talks are given on the respective pages (*top*, *right*).

White Dwarfs in Gaia DR1, DR2, EDR3, and DR3

Stefan Jordan

Astronomisches Rechen-Institut, Zentrum für Astronomie, Universität Heidelberg, Mönchhofstraße 12-14,
69120 Heidelberg, Germany

The impact of the Gaia catalogs on astrophysics is enormous. Especially after the publication of the 2nd data release, the number of papers using Gaia data has increased to about five per calendar day. With Gaia, the number of known white dwarfs has increased dramatically and about 20 % of all Gaia papers mention white dwarfs. This talk will briefly highlight some of these papers. Afterwards a short overview will be given of the new opportunities provided by the new Gaia Data Release 3, released on June 13, 2022.

White dwarfs in Gaia DR3

M.A. Barstow[1], J-M. Carrasco[2], A. Bragaglia[3], C. Mander[1], G. Thomas[1], S.L. Casewell[1] & M.R. Burleigh[1]

1. School of Physics & Astronomy, University of Leicester, UK.
2. Institut de Ciències del Cosmos, Universitat de Barcelona, Espana.
3. INAF-Osservatorio di Astrofisica e Scienza dello Spazio di Bolognà, University di Bolognà, Italia.

By the time of EUROWD22, the third full release of Gaia data products, DR3, will have taken place in June 2022. In addition to further improvements in the quality of the photometric and astrometric data already available in DR2 and eDR3, new data products will be available that will provide important advances in the study of white dwarfs. Multi-band synthetic photometry will be produced for selected DR3 objects, including a sample of $\approx 100,000$ white dwarfs with Gaia G < 20. This Gaia Catalogue of Synthetic Photometry (GCSP) - WD, contains synthetic magnitudes computed from the Gaia BP and RP spectra for several standard photometric systems, including Johnson, SDSS and JPLUS. In addition, non-single star (NSS) classifications will be made available for several hundred thousand objects, which facilitate the search for double degenerate binaries and Sirius-like systems. This paper will present early results from the analysis of these new data products, provide guidance on their use and discuss some of their limitations.

Synthetic photometry and the white dwarf luminosity function in Gaia DR3

Chris Mander[1], Martin Barstow[1], Sarah Casewell[1], Jan Rybizki[3], George Thomas[1]

[1]*School of Physics and Astronomy, University of Leicester, UK*
[3]*Max Planck Institute for Astronomy, Heidelberg, Germany*

The White Dwarf Luminosity Function (WDLF) is a fundamental tool for analysing the properties of the local WD population, defined as the number of white dwarfs per cubic parsec as a function of unit luminosity. The WDLF of nearby stars can provide information on the age and evolution of the Galaxy and is a direct constraint on the death rate of local low-mass stars. The WDLF has previously been calculated from samples at a maximum distance of 25 pc (Holberg et al., 2016), 40 pc (Limoges et al., 2015), and most recently 100 pc (Gaia Collaboration; Smart et al., 2021). Each increase in distance has resulted in an increased sample size, which has improved the accuracy and resolution of observed WDLFs. We present early efforts using Gaia eDR3 data to extend the maximum distance limit of the local WDLF beyond 100 pc with the aim of generating a further improved WDLF. We discuss the implications of Gaia DR3 data for our work, which will have released at the time of EUROWD 2022. In addition, we will discuss our aims for future work utilising synthetic photometry of white dwarfs made available in Gaia DR3.

Properties of White Dwarfs in the JJ model based on Gaia EDR3

Akash Vani, Andreas Just, and Kseniia Sysoliatina

Astronomisches Rechen–Institut, Zentrum für Astronomie der Universität Heidelberg, Mönchhofstr. 12–14, 69120 Heidelberg, Germany

The Just-Jahreiß (JJ) model is a semi-analytic chemo-dynamic model of the Milky Way (MW) Galactic disk (Just & Jahreiß 2010) and is a flexible tool for stellar population synthesis. It is based on an iterative solving approach of the Poisson-Boltzmann equation and reconstructs a self-consistent pair of the total vertical gravitational potential and density. The JJ model converts the density profiles to mock samples using PARSEC isochrones for a wide range of metallicities (-2.59 < [Fe/H] < 0.47) with a fine 50 Myr age step. The model also includes MIST and BaSTI isochrones as complementary sets. In the model, each subpoplation of stars is characterised by an age-mtallicity pair, using this we select the best isochrone (closest in metallicity and age) and apply an IMF to get the present-day stellar number densities.

The JJ model has been recently updated and calibrated in the Solar neighbourhood against the *Gaia* DR2 stars. The model has been demonstrated to have a good model-to-data consistency (with a $\sim$ 4% discrepancy in terms of star counts) in the local 1-kpc height cylinder and $\sim$0.1 % discrepancy against the Fifth Catalogue of Nearby Stars (CNS5, Golovin et al. 2022, submitted), a 25-pc volume-limited sample. The model is now generalised to be applicable for a wide range of Galactocentric distances, 4 kpc $< R <$ 14 kpc (Sysoliatina & Just 2021, Sysoliatina & Just 2022, submitted).

All stars with initial masses lower than $\sim$8 $M_{\odot}$, i.e. $\sim$97 % of the stars in our Galaxy, are destined to evolve into white dwarfs (WDs). These stellar remnants have no appreciable sources of nuclear energy. Thus, they will slowly cool and radiate the stored energy over time. WDs are used to infer the ages of different stellar populations and the star formation rate (SFR). However, the stellar libraries that are mentioned above, do not include the evolution of WDs.

Given the importance of these objects, this work deals with extending the JJ model to the WD locus. Currently, we use the initial-final mass relation by Cummings et al. (2018) to bridge the main sequence stellar evolution to WDs. We use solar metallicity BaSTI (Salaris et al. 2022) carbon-oxygen WD isochrones for H atmosphere (type DA) and He atmosphere (type DB) WDs to further evolve a given population in the JJ model. For simplification, we fix the ratio of DA to DB WDs to be 80 % to 20 % for all temperature ranges. To test the JJ model's predictions, we use the CNS5 catalogue, a volume-limited sample of stars within 25 pc and a sub-sample of the GCNS catalogue with a volume of 60 pc. We use the default JJ model parameters, this includes two star formation bursts which happened 0.5 Gyrs and 3 Gyrs ago as defined in Sysoliatina & Just 2021. We also define a cut at 15 M_G in the data to focus on the late SFR and thus young WDs. We find a good data-to-model consistency, with a discrepancy in the total star count being 1 % against the CNS5 and 3 % against the 60 pc volume sample. However, the model predicts 9 % more WDs than the data (for both samples). Most of these are located near 15 M_G and suggests that the earlier SFR must be adapted. The model also predicts vertical density profile, W velocity profile, age and mass distributions of WDs. Currently, the model predicts a higher DA mass distribution peak at 0.61 $M_{\odot}$. The next planned step is to calibrate the SFR based on old WDs in the solar neighbourhood and revisit these properties.

Completing the 40 pc spectroscopic sample of Gaia white dwarfs

Mairi O'Brien

Department of Physics, University of Warwick, Coventry CV4 7AL, UK

The Gaia spacecraft has enabled us to create a catalogue of high-confidence white dwarf candidates in the local stellar population, using its highly accurate photometry and parallax measurements. To confirm the nature of these white dwarf candidates, we must obtain spectroscopic observations for each source. With spectroscopic data, we can infer the atmospheric composition of the stars and therefore accurately fit their photometry. We can also fit the spectra using state-of-the-art model atmosphere codes to determine the effective temperatures, masses, and cooling ages of the white dwarfs. We now have a volume-complete sample of around 1100 white dwarfs within 40 pc with spectroscopic follow-up. This sample covers eight times the volume of the previous largest volume-complete 20 pc sample. I will present an analysis of the spectroscopic observations of the remaining 254 white dwarf candidates from Gaia EDR3 in the southern hemisphere. When combined with already published spectroscopy, the 40 pc sample now has roughly 97% spectroscopic completeness. I will discuss some of the notable white dwarfs in this southern hemisphere sample, including metal-polluted white dwarfs with carbon lines, and highly magnetic white dwarfs. I will also explain how we can use the volume-complete 40 pc sample to study star formation history in the stellar neighbourhood, as well as looking at the issues and biases of the sample and how these can be reduced going forward.

A spectropolarimetric survey of white dwarfs in the local 20pc volume

S. Bagnulo[1] & J.D. Landstreet[1,2]

1. Armagh Observatory and Planetarium, College Hill, Armagh BT61 9DG, UK
2. University of Western Ontario, London, Ontario, N6A 3K7, Canada

We have obtained spectropolarimetric observations for about 100 white dwarfs within 20 pc from the Sun, and combined them with previous literature data. This way we have been able to check almost the entire population of about 150 white dwarfs of the local 20 pc volume for the presence of magnetic field, with a sensitivity that ranges from better than 1 kG for most of the stars of spectral class DA, to $\sim$ 1 MG for the featureless white dwarfs. We have also completed the exploration of a larger volume of space for stars in certain age and mass bins. In this talk we will report about the statistical results of our surveys, and in particular how the occurrence of magnetic field correlates with other stellar features such as atmospheric composition, mass and age. We will discuss the implications of our findings for the theories that try to explain the origin of magnetic fields in degenerate stars.

A neural network-based algorithm for fast classification and analysis of large samples of white dwarf stars

Olivier Vincent, Pierre Bergeron, Patrick Dufour

Département de Physique, Université de Montréal, Montreal, QC H3C 3J7, Canada

The next generation of spectroscopic surveys will provide spectra for hundreds of thousands of white dwarf candidates. Such unprecedented volumes of data will require fast, automated tools to quickly sort through typical objects and to identify interesting cases. Up until now, spectroscopic classification of white dwarfs has mostly been done by eye. While feasible for modest numbers of stars, such method does not scale well and is prone to many human biases. We train an ensemble of convolutional neural networks on SDSS DR16 objects and show that this method offers a promising alternative, providing consistent and quantifiable classification for thousands of stellar objects in just a few minutes. We also investigate the use of sequential neural posterior estimation methods to determine stellar parameters of DA and DB white dwarfs. The networks are trained on synthetic SDSS-quality spectra. We first verify the quality of the estimated posteriors via simulation-based calibration and predictive checks. We then apply our networks on SDSS DR16 spectra and compare our results with those published in the literature.

A survey of white dwarf merger remnants with ZTF

Ilaria Caiazzo

Division of Physics, Mathematics and Astronomy, California Institute of Technology, Pasadena, CA 91125, USA

Recent results from Gaia and from stellar population synthesis have shown that a large fraction of single massive white dwarfs is the result of double-degenerate mergers. Finding and characterizing a population of white dwarfs resulting from mergers can help us constrain this fraction as well as understand the properties of merger remnants. Thanks to the Zwicky Transient Facility, we are finding a large sample of massive white dwarfs that are likely remnants of mergers because of their strong magnetic field and short rotation periods. In my talk, I will present the first results of this search as well as some extremely peculiar white dwarfs that stood out because of their fascinating nature.

White Dwarfs in the HETDEX survey

Barbara G. Castanheira, Beau Brooks

Baylor University

In this presentation, I will show the first results of our survey of white dwarfs that were discovered in the Hobby-Eberly Telescope Dark Energy Experiment (HETDEX). Observations were done using the VIRUS Integral-field Units (IFU) array, covering between 3500Åand 5600Å, with resolution R 2Å. As a by-product of the first data release of the dark energy survey, we have obtained high signal-to-noise spectrum of $\sim$100 white dwarfs down to a magnitude of 21, in the g-band. We cross-matched with Gaia and Sloan Digital Sky Survey (SDSS) data to reliably fit the spectra for effective temperature and surface gravity. The primary science goal of our project is to produce a unique magnitude-limited catalog of as many as 10,000 spectroscopically confirmed white dwarfs. Given we are using IFU data, our survey is free of the selection biases that plagued the SDSS. Our final survey will produce a WD luminosity function five magnitudes fainter than the one derived from the Palomar-Green survey (PG) and with a similar number of faint stars as the one from SDSS.

The ELM Survey South

Alekzander Kosakowski[1], Mukremin Kilic[2], & Warren R. Brown[3]

[1]*Department of Physics and Astronomy, Texas Tech University, Lubbock, TX 79409, USA*
[2]*Homer L. Dodge Department of Physics and Astronomy, University of Oklahoma. 440 W. Brooks St., Norman, OK, 73019 USA*
[3]*Smithsonian Astrophysical Observatory, 60 Garden St., Cambridge, MA, 012138 USA*

Extremely Low Mass (ELM) white dwarf binaries are an important class of object for studying the effects of compact binary evolution, including common envelope evolution, gravitational wave emission, and sub-Chandrasekhar merger products. A large sample of ELM white dwarf binaries is thus required to obtain meaningful statistics on these evolutionary stages and to study the population as a whole.

The ELM Survey has identified over 100 low-mass white dwarf (LMWD) binaries to date, but only a few are located in the Southern sky. The original ELM Survey South's target selection used photometry from early data releases of SkyMapper and VST ATLAS to expand the ELM Survey to the South, but found a large fraction of their candidates to be contaminants such as subdwarfs or single white dwarfs.

Here we continue the search for ELM white dwarf binaries, primarily in the Southern sky, using a Gaia-based selection with Gaia DR2 and eDR3. We identify over 70 candidate LMWD binaries based on our spectroscopic follow-up and present a summary of our analysis to two dozen of these for which we obtained complete orbital solutions. We discuss the properties of these new binaries as part of the larger population and present a target selection region which aims to maximize the number of known LMWDs and facilitate efficient follow-up of our remaining spectroscopic candidates.

Local stellar formation history from the 40pc white dwarf sample

Elena Cukanovaite, Pier-Emmanuel Tremblay, Jack McCleery, Mairi W. O'Brien

Department of Physics, University of Warwick, Coventry CV4 7AL, UK

The stellar formation history is a major ingredient needed to understand the evolution of the disk and halo components of the Milky Way. This knowledge can then be applied more broadly to similar galaxies. White dwarfs have been previously utilised for this purpose, providing a beneficial alternative to main sequence stars. With the advent of *Gaia* and its numerous releases, the number of known white dwarfs has experienced a magnitude increase. Using *Gaia* McCleery et al. (2020) and O'Brien et al. (in prep) have curated a 40pc sample of white dwarfs with spectroscopic completeness of around 96%, making it the largest volume-complete sample to date. Having a complete sample brings advantages in terms of population synthesis models, as it removes the need to include complex bias corrections. Therefore, in this talk we aim to present the stellar formation history derived from the 40pc white dwarf sample, and contrast the findings with previous studies of both white dwarfs and main sequence stars.

McCleery, J., Tremblay, P.-E., Gentile Fusillo, N. P., et al. 2020, MNRAS, 499, 1890
O'Brien W. M., et al., *in preparation*

Star Formation History – The Story As Told By The Galactic White Dwarf Luminosity Functions

Marco C. Lam

School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel 69978

With the state-of-the-art Gaia astrometry, the number of confirmed white dwarfs has reached a few hundred thousands. We have reached the era that small features in the Galactic white dwarf luminosity function (WDLF) can be resolved. We demonstration how we can apply Markov chain Monte Carlo sampling on a set of pre-computed partial-WDLFs to derive the star formation history of their progenitor stellar population.

White dwarfs and the Galactic chemodynamics

Roberto Raddi et al.

Universitat Politècnica de Catalunya, Departament de Física, c/ Esteve Terrades, 5, 08860 Castelldefels, Spain

The Solar neighborhood is a complex ensemble of overlapping stellar populations that have formed at different times and locations in the Milky Way. Although their atmospheres lose memory of their past lives, white dwarfs behave as regular astrophysical clocks that can help us to trace the star formation history of our Galaxy, as well as its stellar dynamics and the local age - velocity dispersion relation. White dwarfs in wide binary systems with non-degenerate stars share the same chemical composition of their companions. Hence, they can also trace the chemo-dynamical evolution of the Solar neighborhood as a function of time. We will present the results of our recent paper dissecting the 6D kinematics of white dwarfs in isolation and in common proper motion pairs. Moreover, we will discuss new results on the chemical evolution of the Solar neighborhood and how it can be traced by white dwarfs thanks to the synergy between Gaia and spectroscopic surveys.

A modern look at the white dwarf equation of state and at the binary white dwarf population

Nadia Zakamska (1,2), Vedant Chandra (3), Hsiang-Chih Hwang (2)

(1) Johns Hopkins University, (2) Institute for Advanced Study, (3) Harvard University

Astrometry from Gaia, deep variability surveys and large-area Galactic spectroscopic surveys are enabling novel probes into white dwarf astrophysics, and in particular are allowing us to tackle anew the search for ultra-compact binaries containing white dwarfs that may be Type Ia supernova progenitors. Specifically, SDSS-V will obtain time-resolved spectroscopy of tens of thousands white dwarfs over the next several years. I will discuss successes and challenges of analyzing large spectroscopic datasets of white dwarfs and the utility of machine-learning techniques for this problem. I will then describe applications of these methods to recent and emerging spectroscopic data. I will present new measurements of the white dwarf equation of state, as well as a sample of newly discovered white dwarf binaries.

CSPN in the HASH database - Investigations and Insights

Quentin A Parker & Andreas Ritter

1. The Laboratory for Space Research, Cyberport 4, Hong Kong SAR, PRC
2. Department of Physics, CYM Physics Building, The University of Hong Kong SAR, PRC

Until recently, only about 20% of all known PNe had an equivocally identified CSPN to help relate PN properties to the underlying properties of the CSPN. These are known to be extremely varied, encompassing a wide variety of stellar types and characteristics ranging from pop II Wolf-Rayet stars ([WR]), different kinds of white dwarfs (DA, DAO, DO), PG1159 stars, Weak emission line stars (WLES) and early and late O(H) and Of(H) stars. Determining the variation and fractions of the diverse population of CSPN is vital for understanding their host PNe and their morphologies, shaping mechanisms, energetics and the key role this important but brief phase of stellar evolution plays in Galactic chemical enrichment and the ISM mass budget. If we are to undertake such studies we must first be confident that any identified CSPN is actually the bona-fide progenitor for the surrounding nebula and also try to ensure we have uncovered as many CSPN as possible so they are properly representative of the overall CSPN population. HASH helps with this mission. HASH (Hong Kong/AAO/Strasbourg H-alpha PN catalogue) is a PNe mutliwavelength database of all currently known Galactic and Magellanic Cloud PNe that has provided a powerful, new resource for the community to study both PNe and their CSPN with over 500 users in more than 60 countries. In this talk I will present preliminary results on the independently derived Galactic CSPN population now available through HASH and make some comparisons to the findings with preliminary Gaia results and make some brief comments on what this means for the study of CSPN in general.

Three-dimensional simulations of turbulently-driven deflagration-to-detonation transition in near-Chandrasekhar type Ia supernovae

Mark Ivan G. Ugalino[1], Robert T. Fisher[1], Alexei Y. Poludnenko[2], Vadim N. Gamezo[3]

[1] *University of Massachusetts Dartmouth, North Dartmouth, Massachusetts*
[2] *University of Connecticut, Storrs, Connecticut*
[3] *Naval Research Laboratory, Washington DC*

Type Ia supernovae (SNe Ia) are luminous events which serve as standardizable candles. SNe Ia are crucial in measuring cosmic acceleration and enrich the interstellar medium with their nucleosynthetic yields. While all normal SNe Ia must undergo a detonation, we do not have a complete understanding as to how a detonation arises from the flame ignited within the white dwarf. In this work, we have applied for the first time a laboratory-validated first-principles mechanism of a turbulently-driven deflagration-to-detonation transition in 3D full star simulations of near-Chandrasekhar white dwarfs. We will characterize conditions at the onset of the tDDT and discuss the observable signatures as well as the implications for the broader SN Ia progenitor problem.

He Flash due to mass transfer from high-entropy He WDs

Tin Long Sunny Wong[1] & Lars Bildsten[1,2]

[1] *Department of Physics, University of California, Santa Barbara, CA 93106, USA*
[2] *Kavli Institute for Theoretical Physics, University of California, Santa Barbara, CA 93106, USA*

Most previous studies of mass transfer from a He WD onto a CO WD focused on the case of a strongly degenerate (low-entropy) donor, leading to high mass transfer rates, $\dot{M} \sim 10^{-6}\,M_\odot\,\mathrm{yr}^{-1}$ that declines with time, initially triggering many weak recurrent He novae. As $\dot{M}$ declines, there may be, at most, one dynamical He shell flash capable of detonating. In this talk, I will describe new models using the MESA stellar evolution code of mass transfer from a high-entropy, $0.14 - 0.20\,M_\odot$ He WD onto a $0.9 - 1.1\,M_\odot$ CO WD. These lead to lower mass transfer rates, $\approx 10^{-7}\,M_\odot\,\mathrm{yr}^{-1}$, so that the first He flash occurs with a He shell mass of $\approx 0.02 - 0.05\,M_\odot$, large enough to detonate. I will discuss the binary evolution pathways that produce these high-entropy He WD donors and highlight that these are promising candidates for those double-detonation type Ia supernovae where recent interpretations point to He shell masses in this same range.

AREPO White Dwarf merger simulations resulting in edge-lit detonation and run-away hypervelocity companion

Uri Pierre Burmester,[1] Lilia Ferrario,[1] Rüdiger Pakmor,[2] Ivo Seitenzahl,[3] and Matthew Hole[1]

[1]*Mathematical Sciences Institute, Australian National University, Canberra ACT 0200, AU*
[2]*Max Planck Institute for Astrophysics, Karl-Schwarzschild-Strasse 1, 85748 Garching, DE*
[3]*School of Science, UNSW Canberra, ADFA, PO Box 7916, Canberra BC ACT 2610, AU*

We present a series of simulations generated with the moving-mesh code AREPO to model the merger of two White Dwarf (WD) stars. The primary is a carbon-oxygen (CO) WD with a mass of 1.1 and the secondary is a helium (He) WD with a mass of 0.35 . We have found that such a merger resulted in an edge-lit detonation. Helium burning begins at the base of the primary's helium layer after a period of sustained mass deposition while the Carbon detonation occurs 0.2-0.3 seconds later below the helium detonation layer. The variable composition WD structure was produced using the White Dwarf Evolution Code (WDEC), which generates 1D structures from a set of inputs that includes total mass and effective temperature. This represents an improvement on various prior works which are limited to isothermal, constant composition structures. The time evolution of the merger and associated nuclear reactions are computed by AREPO, which has the ability to evaluate the equations of Ideal MHD using a Finite Volume Method (FVM) on a large, unstructured grid.

Hyperrunaway hot subdwarfs from supernovae type Ia

Max Pritzkuleit[1], Stephan Geier[1], Patrick Neunteufel[2], Matti Dorsch[1,3]

[1] *Institut für Physik und Astronomie, Universität Potsdam, Haus 28, Karl-Liebknecht-Str. 24/25, 14476 Potsdam-Golm, Germany*

[2] *Max Planck Institut für Astrophysik, Karl-Schwarzschild-Straße 1, 85748 Garching bei München, Germany*

[3] *Dr. Karl Remeis-Observatory & ECAP, Friedrich-Alexander University Erlangen-Nürnberg, Sternwartstr. 7, 96049 Bamberg, Germany*

Hot subdwarf stars of spectral type O and B are the products of binary star evolution. One of the most extreme outcomes are hyperrunaway hot subdwarfs, which were ejected by the supernova explosion of a former white dwarf companion. The resulting ejection velocity can be fast enough to escape the galactic potential. However, US 708 is, so far, the only known object most likely originating from this scenario. Using the most recent Gaia data and theoretical predictions, we are searching for more of these objects. These stars can then be used to reconstruct the masses of the exploded white dwarfs where it is still under debate at which mass a white dwarf is able to explode. In my talk, I will provide a brief outline of the ejection mechanism, our target selection and a few preliminary results.

Sihao Cheng, Kevin Schlaufman

Johns Hopkins University

Massive white dwarfs provide a unique window to study planet around intermediate mass stars, which are difficult to find. We examined a characteristic signature of giant planets in infrared photometry around young, massive white dwarfs selected with Gaia and cross-matched to Spitzer archival database to search for planets and estimate their occurrence. We found one high-credibility planet candidate and a few marginally credible candidates within 100 pc. They are ideal targets for direct imaging follow-ups using the JWST. The resulting occurrence of giant planets is consistent with the estimate from doppler method.

Investigation of the circumbinary planet in a polar CV DP Leo

K. Wangnok[1], N. Sanguansak[2], P. Irawati[3], and P. Chainakun[1]

[1)] *School of Physics, Institute of Science, Suranaree University of Technology, Nakhon Ratchasima 30000, Thailand*
kittipong.wangnok@gmail.com
[2)] *The Institute for the Promotion of Teaching Science and Technology, Bangkok 10110, Thailand*
[3)] *National Astronomical Research Institute of Thailand, Chiangmai, 50180, Thailand*

In this work, we report the long-term photometric observations of DP Leo spanning an additional seven years and adopts the data obtained from the previous literature to investigate the presence of the circumbinary planet around DP Leo. The photometric observation of DP Leo was obtained in 2014-2020 using the 2.4m Thai National Telescope with ULTRASPEC instrument in g', r', and KG5 filters. Aperture photometry is performed using the HiPERCAM pipeline. From our investigation, the light curve of DP Leo contains the white dwarf, the red dwarf, the spot, and the stream. The stream in the light curves is assumed as a very small contribution. The composite model is constructed to derive the model of all and white dwarf contributions using lcurve software with lroche package. The light curve fitting is optimized using the Levenberg-Marquardt algorithm. The Sigmoid function is used to derive the mid-eclipse time of the white dwarf and all contributions. The observed time subtracted by the calculated time (O-C diagram) analysis has been performed to study the time variation in the binary stars system using the ephemeris of the mid-eclipse times (T_0) and the accurate orbital period (P_{orb}). The orbital period change can be seen in the result as cyclic change in the O-C diagram. Light Travel Time (LTT) effect is applied to the O-C analysis. The preliminary result of light curve fitting, the O-C analysis, and the presence of the circumbinary planet in DP Leo will be discussed.

Discovery and Characterization of Transiting Planetary Debris Systems with Gaia and ZTF

Zach Vanderbosch, et al.

Division of Physics, Mathematics and Astronomy, California Institute of Technology, Pasadena, CA 91125, USA

White dwarfs that exhibit transits caused by circumstellar planetary debris have a broad range of observational properties that make them difficult both to discover and characterize as a class. Variability timescales that define the transit durations and debris orbital periods range from minutes to months, while the variability itself is often highly irregular and undergoing rapid changes in structure. We present an update to the ongoing search for transiting planetary debris systems using primarily the Gaia and ZTF surveys, and summarize what is currently known about the observational properties of this class, highlighting some of the commonalities and peculiarities among them.

Characterizing the Orbital Periods of Transiting Planetary Debris around White Dwarfs

Joseph Guidry[1], J. J. Hermes[1], Zach Vanderbosch[2]

[1]*Boston University,* [2]*Caltech*

At least 30% of white dwarfs show metal-polluted spectra encoded with the bulk geochemical makeup of accreted extrasolar rocks. Exactly how this planetary debris is delivered to the star's surface remains weakly constrained by observations. We have recently discovered many new members of the new class of white dwarfs showing transits from edge-on planetary debris disks. These transits offer a real-time glimpse into the accretion of planetary debris onto white dwarfs, presenting a unique new laboratory for understanding the pollution of white dwarfs. To date, only four of the 11 known transiting debris systems have measured orbital periods. The light curves of these objects point towards a dichotomy: short- (< 25 hr) and long-period ($>$ weeks) systems. It is therefore crucial to measure more orbital periods to characterize these systems as a class and begin to connect transits to the broader context of pollution. We discuss progress made on new techniques to measure the orbital periods of more transiting debris systems and the ongoing search for more such systems using all-sky time-domain surveys.

White dwarfs and gas discs: the good, the bad, and the weird

Nicola Gentile Fusillo, Boris Gänsicke, Christopher Manser

European Southern Observatory
University of Warwick
Imperial College London

1-2% of all white dwarfs exhibit IR excess flux, indicative of the presence of a planetary dusty debris disc. Among these already rare systems, roughly 4% also display double-peaked emission lines corresponding to various ionic transitions (most commonly the Ca II 850-866 nm triplet), the unmistakable signature of a flat gas disc in Keplerian orbit. These gas disc are the signpost of ongoing disruption events, collisions, or even the presence of a dense planetary body still surviving within the dust disc. Thus studying these systems provides the best opportunity to explore not only the physical properties of the debris discs, but also trace their dynamical evolution. Since the advent of Gaia, the number of known gas-disc systems tripled going from 7 to 21. This increased sample allowed us, for the first time, to study these objects as class and take a first peek at their global properties. However, with these discoveries a surprising degree of diversity is also starting to emerge challenging some of the long standing assumptions about these objects, and giving rise to new questions about the geometry, composition and evolution of these discs. I will give an overview of the diversity found among the known gas discs focusing on some recently identified peculiar characteristics, and I will describe the discovery of a new unique gas-disc system which displays some never-seen-before properties.

Using polluted white dwarfs to understand exoplanetary material

L. K. Rogers[1], S. Xu[2], A. Bonsor[1], P. Dufour[3], B. Klein[4], A. Buchan[1], S. Hodgkin[1], M. Kissler-Patig[5], C. Melis[6], A. Weinberger[7], B. Zuckerman[4]

[1] *Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK*
[2] *Gemini Observatory, 670 N. A'ohoku Place, Hilo, HI 96720, USA*
[3] *Département de Physique, Universit de Montral, C.P. 6128, Succ. Centre-Ville, Montréal, Québec H3C 3J7, Canada*
[4] *Department of Physics and Astronomy, University of California, Los Angeles, CA 90095-1562, USA*
[5] *European Space Agency - European Space Astronomy Centre, Camino Bajo del Castillo, s/n., 28692 Villanueva de la Caãada, Madrid, Spain*
[6] *Center for Astrophysics and Space Sciences, University of California, San Diego, CA 92093-0424, USA*
[7] *Earth and Planets Laboratory, Carnegie Institution for Science, 5241 Broad Branch Rd NW, Washington, DC 20015, USA*

Observations of planetary material *polluting* the atmospheres of ~ 30 percent of white dwarfs provide a unique means to probe the bulk composition of exoplanetary material. Although more than 1000 polluted white dwarfs are known, a small sub-sample have enough species present to investigate the correlation between siderophilic species (e.g. Fe, Ni and Cr) compared to lithophilic species (e.g. Ca, Mg and Si) such that exoplanetary composition and geology can be probed. In order to reach the numbers required for population statistics, more heavily polluted white dwarfs must be discovered and characterised. *Gaia* provides unprecedented access to a large number of newly identified white dwarfs. The most heavily polluted white dwarfs tend to be those which host observable circumstellar dust discs. We present the first results from a large ground based spectroscopic survey which targets newly discovered *Gaia* white dwarfs with dust discs inferred from *WISE* and *Spitzer* infrared excesses. Our high signal-to-noise spectra reveal a plethora of absorption lines for multiple species for each target. Analysing the abundances of the planetary material that polluted these white dwarfs reveals they have accreted material with a large range of volatile content, including two systems that appear to be accreting water-rich bodies. There is also evidence for the accretion of fragments of a core-mantle differentiated body, showing core-mantle differentiation and disruptive collisions are commonplace in exoplanetary systems. In order to obtain *absolute* metal abundances of the pollutant, precise and accurate stellar parameters are required. However, we show instead how elemental ratios are less influenced by imprecise knowledge of stellar parameters and that the conclusions regarding exo-composition and exo-geology are little affected.

Spectral analysis of ultra-cool white dwarfs polluted by planetary debris

Abbigail Elms

Department of Physics, University of Warwick, Coventry, CV4 7AL, UK

We have identified two ultra-cool ($< 4000\,$K) metal-polluted (DZ) white dwarfs WD J2147−4035 and WD J1922+0233 as the coolest and second coolest DZ stars known to date with $\approx 3050\,$K and $\approx 3340\,$K, respectively. Strong atmospheric collision-induced absorption (CIA) causes the suppression of red optical and infra-red flux in WD J1922+0233, resulting in an unusually blue colour given its low temperature. WD J2147−4035 has moderate infra-red CIA yet has the reddest optical colours known for a DZ white dwarf. Microphysics improvements to the non-ideal effects and CIA opacities in our model atmosphere code yields reasonable solutions to observations of these ultra-cool stars. WD J2147−4035 has a cooling age of over 10 Gyr which is the largest known for a DZ white dwarf, whereas WD J1922+0233 is slightly younger with a cooling age of 9 Gyr. Using intermediate-resolution spectroscopy, we have detected sodium and potassium in both white dwarfs, calcium in WD J1922+0233 and lithium in WD J2147−4035. We have identified the magnetic nature of WD J2147−4035 from Zeeman splitting in the lithium line and have also made a tentative detection of carbon, so we have classified this star as DZQH. WD J1922+0233 likely accreted planetary crust debris, while the debris composition that polluted WD J2147−4035 remains unconstrained.

The Origin of Lithium Enhancement in Polluted White Dwarfs

Benjamin C. Kaiser[1], J. Christopher Clemens[1], Simon Blouin[2], Nikos Prantzos[3], Antoine Bédard[4], Erik Dennihy[5], Patrick Dufour[4], Ryan J. Hegedus[1], Joshua S. Reding[1]

1. University of North Carolina at Chapel Hill
2. University of Victoria
3. Institut d'Astrophysique de Paris
4. Université de Montréal
5. Gemini Observatory/NSF's NOIRLab

White dwarfs present the unique opportunity to measure the bulk abundances of extrasolar planetesimals when the planetesimals are accreted by their host white dwarf. Kaiser et al. (2021) and Hollands et al. (2021) recently discovered lithium for the first time in several white dwarfs. The accreted rocky planetesimals appear to be enhanced in lithium compared to the primordial lithium abundance of the Solar System. Three explanations have been offered for this lithium excess: accretion of nucleosynthetically metal-poor material (Kaiser et al. 2021), accretion of continental crust material (Hollands et al. 2021), and accretion of an icy exomoon comprised of icy ring material that was spalled by protons (Doyle et al. 2021). We compare the measured abundances of the planetesimals accreted by these white dwarfs to the predictions of these three hypotheses. We present newly obtained spectroscopic observations of three of the white dwarfs with lithium detections (LHS 2534, WD J1824+1213, and WD J2317+1830) and a new null lithium detection in another cool, metal-polluted white dwarf. Using these new data, we evaluate all three hypotheses and compare their relative merits.

Spectroscopic Characterization of Helium-Dominated Polluted White Dwarfs with Machine Learning

Mariona Badenas-Agusti[1,2], Javier Viaña[2,3], Andrew Vanderburg[2], Sara Seager[4], Patrick Dufour[5,6], Simon Blouin[7]

[1] *Department of Earth, Atmospheric and Planetary Sciences, Massachusetts Institute of Technology, Cambridge, MA 02139, USA*
[2] *Department of Physics, and Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology, Cambridge, MA 02139, USA*
[3] *College of Engineering & Applied Science, 2850 Campus Way, University of Cincinnati, Cincinnati, OH 45219*
[4] *Department of Aeronautics and Astronautics, Massachusetts Institute of Technology, Cambridge, MA 02139, USA*
[5] *Institut de Recherche sur les Exoplantes (iREx), Universit de Montral, Montral, QC H3C 3J7, Canada*
[6] *Departement de physique, Universit de Montral, Montral, QC H3C 3J7, Canada*
[7] *Department of Physics and Astronomy, University of Victoria, Victoria, BC V8W 2Y2, Canada*

For the past decades, spectral modeling of polluted white dwarfs has been a time-intensive process involving manual and iterative work. Recently, other groups have used Machine Learning (ML) to interpolate and efficiently model stellar spectra, but not yet to fit the complex and diverse spectra of polluted white dwarfs. Building upon their work, we present a novel and fast ML architecture for determining the main astrophysical properties of polluted white dwarfs based on their spectra, including their photospheric elemental abundances. In particular, we discuss our latest results for both theoretical and real observations and justify why our methodology, if successful, could open the door to statistical studies of polluted white dwarfs, thus becoming a valuable framework for the study of extrasolar geochemistry.

A White Dwarf Accreting Planetary Material Determined from X-ray Observations

Tim Cunningham[1]

[1]*Department of Physics, University of Warwick*

We have recently made the first direct detection of planetary material accreting onto a white dwarf using X-ray observations. This discovery confirms G29−38 - the prototype of all metal-polluted white dwarfs with detected debris disks as a significant source of soft X-rays. Our detection relied upon a 106 ks exposure with the *Chandra X-ray Observatory* and provides the first direct evidence of ongoing accretion of planetary material onto a white dwarf. From the measured low-energy X-ray emission and modelled X-ray luminosity, we provide the first independent constraint on the accretion rate at such a system, finding an instantaneous accretion rate consistent with modelling of observed photospheric abundances. We measure a relatively low plasma temperature of $kT \approx 0.5\,\mathrm{keV}$, corroborating the predicted bombardment solution for white dwarfs accreting at low accretion rates. I will present this recent discovery and its implications for the study of evolved planetary systems, including the accretion rates and bulk elemental compositions.

Understanding the origin of metal pollution in white dwarf atmospheres through dynamical evolution of planetary systems

Raúl Maldonado[1,2], Eva Villaver[1,3], Alexander Mustill[4], Miguel Chávez[2], Emanuele Bertone[2]

[1] *Universidad Autónoma de Madrid, Madrid, Spain*
[2] *National Institute of Astrophysics, Optics and Electronics, Puebla, Mexico*
[3] *Centro de Astrobiología (CAB, CSIC-INTA), Madrid, Spain*
[4] *Lund Observatory, Lund University, Lund, Sweden*

Nowadays, it is well established that 25-50% of white dwarfs (WDs) show metal pollution in their atmospheres. Based on observational evidence, the current paradigm to explain this phenomenon involves planets surviving the evolution of their host star and the scattering bodies to closer WD distances. In this work, we perform thousands of N-body simulations of systems dynamically analogous to the observed exoplanetary systems, having two to six planets orbiting main-sequence stars which are evolved to the WD phase. The exploration of the parameter space, although not exhaustive, is guided by the properties of the observed systems. Our simulations show that the more planets the system has, the more it will become dynamically unstable when the stellar host becomes a WD and the fraction of four- to six-planet unstable systems is comparable to the prevalence of polluted WDs. Furthermore, simulations with a high multiplicity of planets produce planet-planet scattering events that send a non-negligible number of planets toward the WD crossing the WD's Roche radius and even causing some of them to collide with the WD. Dynamical instabilities in systems with high planet multiplicity may explain the existence of close-in WD planets, as the recently discovered WD 1856 b.

Modeling of accretion disks originating from disrupted rocky/icy planetary bodies around white dwarfs

Ayaka Okuya[1], Shigeru Ida[2], Ryuki Hyodo[3]

[1]*National Astronomical Observatory of Japan, Mitaka, Tokyo, Japan*
[2]*Earth-Life Science Institute, Tokyo Institute of Technology, Meguro-ku, Tokyo, Japan*
[3]*ISAS/JAXA, Sagamihara, Kanagawa, Japan*

A growing number of debris disks have been detected around metal-polluted white dwarfs. They are thought to originate from tidally disrupted planetary bodies and are responsible for metal accretion onto host WDs. Observations have shown that (1) a large number of polluted WDs are inferred to have the accretion rate higher than that predicted by Poynting-Robertson flux, $\dot{M}_{\rm PR}$, and that (2) terrestrial rocky materials would be common polluting sources. Metzger et al. (2012) developed the first accretion disk model that formulates interaction between silicate particles and silicate vapor to propose that (1) and (2) could be reproduced by runaway silicate gas accretion. However, the effect of re-condensation of the silicate gas remained an unsolved issue.

In this study, we revisit this problem by one-dimensional advection/diffusion simulation that consistently incorporates silicate sublimation/condensation and back-reaction forces exerted on gas collectively by particles drifting due to gas drag. We find that because silicate vapor density in the region overlapping the solid particles follows the saturating vapor pressure, no runaway accretion occurs, and (1) cannot be reproduced by mono-compositional rocky disks. As outer planetesimal belts would leave larger mass up to the WD age, infalls of icy-rich bodies may frequently occur. They add volatile vapor (e.g., water vapor) to a silicate disk, which does not condense in the region overlapping the silicate particles. As a result, we demonstrate that volatile vapor enhances the silicate accretion through gas drag as steady accretion and this explains (1). Although the icy-rich composition appears inconsistent with (2), we find that the back-reaction of silicate particles on volatile vapor could produce the volatile accretion rate lower than the silicate accretion rate by an order of magnitude.

Infrared variation at dusty systems

Andrew Swan

University of Warwick

Planetary systems that survive stellar evolution can give access to the bulk compositions of their rocky bodies, whose constituent metals often pollute the atmospheres of their host stars. However, their system architectures remain almost entirely unconstrained. Circumstellar debris is the primary observational contact with the unseen reservoirs of objects that supply the photospheric metals. That debris is most commonly seen through its infrared emission from warm dust. I have shown that the infrared emission is often variable, on timescales ranging from days to decades, establishing these systems as dynamically active environments. The leading hypothesis for the variation is collisional production and destruction of optically thin dust within the closely-orbiting debris. The best-studied system is WD 0145+234, a relatively bright star displaying photospheric metals, an infrared excess, and gas emission. Following a dramatic increase in its infrared flux that lasted for several months, *Spitzer* observations of the aftermath show stochastic brightening events occurring on a timescale of days. I use a simple model to show this behaviour is consistent with ongoing collisions. *JWST* will target WD 0145+234 in the first weeks of science operations. A mid-infrared spectrum will reveal the dust mineralogy, and the near-infrared light curve will be extended on multiple timescales with a 10-s cadence, short enough that we may witness individual collisions. Observations are scheduled to begin shortly before this conference.

Flux Calibration and Balmer Line Shapes

Bart H. Dunlap *et al.*

The University of Texas and McDonald Observatory, Austin, TX, USA

Flux calibration of common photometric systems such as & depends on synthetic white dwarf photometry and fits to Balmer lines of white dwarf standards. However, fundamental parameters (&) of white dwarf stars derived from Balmer line fits show systematic discrepancies from those derived from fits to broadband photometry and parallax, and the results differ depending on the survey and photometric bands used. Motivated by these inconsistencies, we demonstrate a method for recalibrating photometric systems that is independent of Balmer line fits and discuss how we can use these results to better understand model discrepancies. Furthermore, we discuss these results in the context of our measurements of Balmer lines in the laboratory.

Improved Simulations of Stark Broadened Helium Line Profiles for DB White Dwarfs

Patrick Tremblay, Alain Beauchamp, Pierre Bergeron

Département de Physique, Université de Montréal, Montréal, QC H3C 3J7, Canada

The determination of the physical parameters of white dwarfs has been made either through the spectroscopic method or through the photometric method. In the case of DB white dwarfs, a disagreement between the parameters obtained from these two methods motivated a revision of the line profile broadening theory of neutral helium lines, more specifically Stark broadening, in use in the current He I tables at optical wavelengths. By replacing the semi-analytical approach by a simulation environment, a new grid of helium Stark-broadened line profiles, including ion dynamics, has been produced for 12 spectral lines for densities between 10^{14} cm^{-3} and $10^{17.5}$ cm^{-3} and temperatures between $10,000$ K and $40,000$ K. We present synthetic spectra obtained with these new profiles and highlight the differences with previous calculations. We also discuss the possible impact on the determination of physical parameters of DB white dwarfs.

Systematic Calculations of oscillator strengths of intermediatly ionised trans-iron elements for the spectral analysis of hot white dwarfs

S.Gamrath[1],

1. Physique Atomique et Astrophysique, Université de Mons, Belgium

A few years ago, in collaboration with the Institute for Astronomy and Astrophysics of the University of Tubingen, following the discovery of lines of trans-iron elements in the spectrum of the hot white dwarf RE0503289 [1], we began systematic calculations of transition probabilities and oscillator strengths in several heavy elements in their moderately ionization stages (see e.g. [2]). With those brand new theoretical data, extreme overabundances, due to radiative levitation, were highlighted in RE 0503-289 [3] for many elements. However, for that kind of spectral analysis of hot compact stars to be reliable, non-local thermodynamic equilibrium (NLTE) model-atmospheres have to be used. Contrary to LTE models, where occupation numbers of atomic levels are determined by Saha and Boltzmann equations, they have to be determined in detail, i.e. all radiative and collisional transitions between all levels have to be considered. In other words, for bound-bound transitions reliable radiative parameters are required, not only for lines that are identified in the observation but for the complete model atoms that are considered in the model-atmosphere calculations. At the conference we will present a global overview of those calculations and we will show brand new radiative decay rates for Bromium, Caesium and Silver ions. Those data were computed using the pseudo-relativistic Hartree Fock (HFR) method [4] taking core-polarization (CPOL) effects into account. The method used can therefore be called a HFR+CPOL approach [5,6]. For each ion, this method was combined with a semi-empirical procedure to optimize some radial integrals by fitting the calculated energy levels with available experimental data (often very rare in the litterature tough).

References

1. K. Werner et al., Astrophys. J. 753, L7 (2012)
2. T. Rauch et al., ASP Conf. Ser. 509, 183 (2017)
3. P. Francois, M. Spite and F. Spite, Astron. Astrophys. 274 (1993) 821-824
4. R.D. Cowan, The Theory of Atomic Structure and Spectra, Univ. California Press, Berkeley (1981)
5. P. Quinet et al., Mon. Not. R. Astr. Soc. 307, 934 (1999)
6. P. Quinet et al., J. Alloys Comp. 344, 255 (2002)

Super Metal-Rich Pre-White Dwarfs as High-Precision Atomic-Physics Laboratories

Alexander Landstorfer

Institute for Astronomy and Astrophysics, Eberhard Karls Universität Tübingen, Sand 1, 72076 Tübingen, Germany

EC 11481–2303, Feige 110, and PG 0909+276 are pre-white dwarf stars that have been shown to exhibit extreme iron-group element (Ca − Ni) overabundances. With very high resolution and high signal-to-noise ratio spectra of the space telescope imaging spectrograph, detailed spectral analyses could be performed. Modeled and observed line strengths were then compared for more than 450 isolated absorption lines, which gave the opportunity to evaluate the quality of existing atomic data of certain iron-group element ions. Considering the uncertainty of the analysis and evaluation procedure, an upper limit for the uncertainty of the underlying atomic data was established. Then, strong, reliable isolated absorption lines were found, which are recommended to use as reference points for abundance determinations in similar objects.

New Transition Probabilities for Trans-Iron Elements: Zn IV

A. Wajid

Institute for Astronomy and Astrophysics, Kepler Center for Astro and Particle Physics, Eberhard Karls University, Tübingen, Germany

Most of our knowledge about stars comes from the interpretation of their spectra. Spectral analysis based on adequate model atmospheres is a pre-requisite to determine precisely photospheric properties like effective temperature, surface gravity, and element abundances. For hot stars, spectral analysis based on non-local thermodynamic equilibrium (NLTE) model-atmosphere technique is mandatory. For the NLTE modeling, reliable transition probabilities are required, not only for those (few) prominent lines that were identified in the observation but for the complete model ions which are used in the model-atmosphere calculations.

We present highly accurate transition probabilities of Zn IV lines in the ultraviolet wavelength region. These were calculated using Cowan's atomic code based on the pseudo-relativistic Hartree-Fock (HFR) method. A large number of interacting configurations were considered for ab initio calculations and the optimized energies were used to produce accurate transition probabilities and Ritz wavelengths for the parametric calculations. An erroneous wavelength would yield delusive transition probabilities. Here, we critically evaluated all the reported spectroscopic Zn IV data, and the optimized levels belonging to the $3d^9$, $3d^84s$, $3d^84p$, and $3d^84d$ were used in the parametric calculations. We compare our results with other calculations and observations of the DA-type white dwarf G191−B2B.

Systematic uncertainties in the characterisation of He-dominated metal-polluted white dwarfs

Paula Izquierdo

Department of Physics, University of Warwick, Coventry CV4 7AL, UK

The two most employed methods to obtain the photospheric parameters of white dwarfs fit spectroscopic or photometric data, respectively. These two techniques do not always lead to consistent parameters, but the discrepancies are alarmingly large for helium-dominated white dwarfs. Independent studies usually claim the differences arise from the use of distinct methodologies, versions of the synthetic spectra or to the observed data. However, the published uncertainties just quote, typically, the statistical errors, which underestimate the actual values, which should take into account the dramatic effect of the systematics. We have tackled this situation by characterising a sample of 13 helium-dominated white dwarfs with the spectroscopic and photometric technique, using up to three different spectroscopic and photometric data for each star. We arrived at mean absolute differences of $\simeq 570\,\mathrm{K}$, $\simeq 0.27\,\mathrm{dex}$ and $\simeq 0.23\,\mathrm{dex}$ for , and , respectively, when fitting model spectra to diverse spectroscopic data. The photometric fits provide mean absolute differences up to $\langle\Delta\rangle = 930\,\mathrm{K}$ and $\langle\Delta\rangle = 0.10\,\mathrm{dex}$. We suggest these values to be adopted as the minimum uncertainties when publishing atmospheric parameters from spectroscopic and photometric fits, respectively. Besides, with the aim of investigating the effect of the assumed and often unrealistic chemical composition on the best-fit atmospheric parameters, we carried out the data modelling using synthetic spectra of three different chemical compositions: (1) pure helium, (2) helium-dominated atmospheric models with traces of hydrogen and (3) hydrogen plus metals in helium-dominated photospheres. In general, pure helium model spectra result in larger than those derived from DBA, while the differences are also notable but change from spectroscopic to photometric data. The addition of metals does also affect the best-fit parameters, but the change is less dramatic than in the previous case.

A detailed modeling of the DO-to-DA spectral evolution

Antoine Bédard, Pierre Bergeron, Pierre Brassard

Département de Physique, Université de Montréal, Montréal, QC H3C 3J7, Canada

The variation of the fraction of helium-atmosphere white dwarfs along the cooling sequence conclusively reveals that spectral evolution takes place among white dwarfs. In particular, at high temperature ($T_{\rm eff} > 30,000$ K), it is empirically well established that $\sim 2/3$ of all helium-rich DO stars eventually turn into hydrogen-rich DA stars. This transformation is usually interpreted as the result of the upward diffusion of residual hydrogen, although this process remains poorly studied from a theoretical perspective. In this talk, I will present state-of-the-art evolutionary calculations that follow the diffusion and mixing of residual hydrogen in hot helium-rich white dwarfs. I will then discuss a few interesting implications of these models for our understanding of spectral evolution. More precisely, I will show that our calculations (1) allow us to constrain the total hydrogen content of hot DO white dwarfs; (2) indicate that the so-called convective dilution mechanism, which is generally believed to turn DA stars into DB stars at low temperature ($T_{\rm eff} < 30,000$ K), is actually unlikely to occur in nature; (3) provide new insights into the long-standing problem of the origin of hydrogen in cool DBA white dwarfs.

Spectral analysis of hot DA- and DAO-type white dwarfs

Semih Filiz, Thomas Rauch, Klaus Werner

University of Tübingen, Germany

We aim to understand the spectral evolution of a small subgroup of H-rich WDs, the so-called hybrid (or DAO) WDs which exhibit both, H and He lines in their spectra. Though small in number, they represent an evolutionary phase run through by the majority ($\approx 75\%$) of all WDs. We started a NLTE analysis of UV and optical spectra of 36 hot ($T_{\mathrm{eff}} > 60\,000\,\mathrm{K}$) WDs which allows, together with distances precisely measured by Gaia, to locate them in the HRD and to derive their stellar parameters (M, R, L). We measure metal abundances to shed light on the question, when and how the hybrid WDs transform into helium-free objects because of gravitational settling of elements. The results will help to clarify the relative importance of the different physical processes acting on helium and metal abundances. First results indicate that previous analyses using Balmer and Lyman lines often significantly under- or overestimated effective temperatures.

HST/COS Ultra-Violet high-resolution spectroscopic survey of DA White Dwarfs

Snehalata Sahu[1], Boris Gänsicke[1], Pier-Emmanuel Tremblay[1], Detlev Koester[2]

[1] *Department of Physics, University of Warwick, Coventry, CV4 7AL, UK*
[2] *Institut für Theoretische Physik und Astrophysik, University of Kiel, 24098 Kiel, Germany*

We present the analysis of an ultra-violet (UV) high-resolution HST/COS survey of 263 DA white dwarfs (WDs), which includes the first spectroscopic observations of 25 new WDs discovered by Gaia. We discuss in detail the comparison of our results with previous studies, and the nature of outliers identified from the UV fits. We have used an updated grid of Koester models to fit the flux-calibrated COS spectra of the WDs and to determine their effective temperatures ($T_{\rm eff}$) and surface gravities ($\log g$), which are found to range from $12,000 < T_{\rm eff} < 30,000\,$K, and, $7 \leq \log g < 9.2$ respectively. The fit routine that we have developed uses the reddening values from 3D STILISM and Gaia EDR3 parallaxes to constrain the radius, and thereby $\log g$. We have implemented two different mass-radius (MR) relations in our fitting, that of the Montreal group (Bedard et al. 2020) and that of the Argentinian group (Althaus et al. 2013), and, compared the results. Our comparison suggests that the fit parameters obtained from the Argentinian MR relation are in better agreement with the published values than the Montreal MR for WDs with $\log g < 8$. Overall, the atmospheric parameters ($T_{\rm eff}$ and $\log g$) obtained from the UV fit are in good agreement with the previous studies, that were almost entirely based on optical data (e.g. Gentile Fusillo et al. 2021). However, $\approx 25\%$ of the sample show large deviations from the published photometric/spectroscopic estimates suggesting that these can be unresolved WD plus low-mass companions or double degenerates.

Spectral evolution and calcium white dwarfs in J-PLUS

C. López-Sanjuan[1], P-E. Tremblay[2], A. Ederoclite[1], and the J-PLUS collaboration

[1] *Centro de Estudios de Física del Cosmos de Aragón (CEFCA)*
[2]

We complement the *Gaia*-based catalog presented in Gentile Fusillo et al. 2021 with the optical photometry from the Javalambre Photometric Local Universe Survey (J-PLUS) DR2, covering 2 176 deg^2 with 12 passbands ($ugriz$ + 7 medium bands). We define a common sample of 5 926 white dwarfs with $r < 19.5$ mag and derive their effective temperature ($T_{\rm eff}$), surface gravity, mass (M), and atmospheric composition (H- *versus* He-dominated). We also estimate the presence of polluting metals with the $J0395$ filter in J-PLUS, sensitive to the calcium H+K absorption.

We find that (i) the fraction of white dwarfs with He-dominated atmospheres ($f_{\rm He}$) has a minimum of $8 \pm 2\%$ at $T_{\rm eff} > 20\,000$ K. Then, $f_{\rm He}$ increases by $21 \pm 3\%$ between $T_{\rm eff} \sim 20\,000$ K and $T_{\rm eff} \sim 5\,000$ K. (ii) The mass distribution at $d < 100$ pc for H-dominated white dwarfs agrees with previous work, presenting a dominant $M = 0.59\,M_\odot$ peak and an excess at $M \sim 0.8\,M_\odot$. This high-mass excess is absent in the He-dominated distribution, which presents a single peak. (iii) The fraction of white dwarfs with calcium H+K absorption increases from nearly zero at $T_{\rm eff} \sim 14\,000$ K to 15% at $T_{\rm eff} \sim 6\,000$ K. This trend reflects the dependence of the calcium absorption intensity on both the temperature and the [Ca/He] abundance. (iv) We defined a sample of 39 white dwarfs with high probability ($> 99\%$) of having polluting metals. 20 sources are already classified as DZs in the literature, and we confirmed 6 more as DZs with new OSIRIS/GTC spectroscopy.

The medium bands from J-PLUS complement the *Gaia* data to derive atmospheric compositions and spot the presence of polluting metals. These analysis will be improved thanks to J-PAS, that with 56 medium bands of 145 nm spaced by 10 nm to cover the optical range will provide low-resolution ($R \sim 50$) data down to $r = 21.5$ mag.

Rotation periods and surface magnetic field structures of young weak-field magnetic white dwarfs

John Landstreet[1,2] & Stefano Bagnulo[2]

1. Armagh Observatory and Planetarium, College Hill, Armagh BT61 9DG, UK
2. University of Western Ontario, London, Ontario, N6A3K7, Canada

Magnetic fields have been detected and studied in white dwarfs (WDs) for more than 50 years, but these fields have been modelled in detail for fewer than a dozen WDs. In order to understand the nature one of these fields, we must obtain detailed information about the structure of the magnetic field over the surface of the host star. To obtain this information, it is necessary to observe the field from multiple directions as the WD rotates, and to model the variations observed in both intensity and (at least circular) polarisation in spectral lines. We have obtained suitable spectropolarimetric data for four young (cooling ages 50 – 600 Myr) magnetic WDs which have fields of the order of hundreds of kG, determined their rotation periods (between 0.059 to 4.7 d), and carried out magnetic modelling. We describe the results of this work, and discuss the implications.

Magnetic White Dwarfs rich in Hydrogen

L. L. Amorim and S. O. Kepler

Instituto de Fsica, Universidade Federal do Rio Grande do Sul, Brazil

The way to understand nature and its laws is through the study of matter under the most diverse conditions. In this context, white dwarfs prove to be an excellent research laboratory, as they may have temperatures, pressures, and magnetic fields that are unattainable on Earth. To better understand how these three physical parameters interact with each other and with other stellar features, we determined the magnetic field strength for 808 hydrogen-rich white dwarfs. The spectra observed with the Sloan Digital Sky Survey were adjusted using atmospheric models that consider the Zeeman effect due to the magnetic field at each point in the stellar disk. In addition, we determined the period of photometric variability for 380 of these white dwarfs observed with the Transiting Exoplanet Survey Satellite and looked for correlations with the other quantities. We found that the white dwarfs with higher magnetic fields tend to have higher masses, lower temperatures, and a crystallization process that has already begun. This reinforces the hypothesis that the field is being generated and/or amplified already in the cooling process of the white dwarf. Our work constitutes the most extended determination of magnetic fields and variation period of white dwarfs to the present day.

Spectrophotometric analysis of hydrogen rich magnetic white dwarf stars

François Hardy

Dpartement de Physique, Universit de Montral, Canada

About 10-15% of white dwarf stars are categorized as magnetic (MWD). Although spectroscopic, photometric and astrometric data have multiplied over the past decade, no homogeneous analysis of these stars has been performed since Külebi's (2009) study. In this presentation, I will show, based on state-of-the-art models, the results of the analysis of all hydrogen-rich MWDs found in the Montreal White Dwarf Database. The properties of the sample, as well as the structure and evolution of the magnetic field in these stars will also be discussed.

Spectroscopic Variability of Magnetic White Dwarfs

Adam Moss[1], Mukremin Kilic[1], Pierre Bergeron[2]

[1]*Department of Physics and Astronomy, University of Oklahoma, Norman, OK, USA*
[2]*Department of Physics, University of Montreal, Montreal, Quebec, Canada*

The origin of strong magnetic fields ($B \geq 1$MG) in white dwarfs (WDs) remains a mystery. One proposed scenario is the creation via a double WD merger. Such products are expected to rotate on the order of minutes and result in a complex magnetic field structure. Modulations in this field can manifest in the Zeeman-split absorption lines, with shifting line centers as the WD rotates. Here we report our findings on 7 WDs with rapidly shifting Zeeman-split Hα components in their spectra. All data was taken with the Gemini Observatory 8-meter telescope. Our Gemini spectroscopy show several of our targets rotate on the order of minutes, suggesting a double WD merger origin. We fit our spectra with an offset dipole model and find that the spectroscopic variations arise from the changes in the average field strength as the WD rotates, further confirming the fast-rotating nature and complex field structure of these objects.

Update on UHE white dwarfs

Nicole Reindl[1], Semih Filiz[2], John D. Landstreet[3,4], Stefano Bagnulo[4], Jiri Krticka[5], Klaus Werner[2], Veronika Schaffenroth[1], Stephan Geier[1], Ingrid Pelisoli[6], S. O. Kepler[7]

[1] *Institut für Physik und Astronomie, Universität Potsdam, Haus 28, Karl-Liebknecht-Str. 24/25, 14476, Potsdam-Golm, Germany*
[2] *Institute for Astronomy and Astrophysics, Kepler Center for Astro and Particle Physics, Eberhard Karls University, Sand 1, D-72076 Tübingen, Germany*
[3] *Armagh Observatory and Planetarium, College Hill, Armagh BT61 9DG, UK*
[4] *University of Western Ontario, London, Ontario, N6A3K7, Canada*
[5] *Department of Theoretical Physics and Astrophysics, Masaryk University, Kotlářská 2, 611 37 Brno, Czech Republic*
[6] *Department of Physics, University of Warwick, Coventry, CV4 7AL, UK* [7] *Instituto de Física, Universidade Federal do Rio Grande do Sul, 91501-900 Porto-Alegre, RS, Brazil*

What happens when a star transforms into a white dwarf? Admittedly, for about 10% of all stars in the universe we fail to answer this question, because – suddenly – these freshly born white dwarfs display weird absorption lines, which were tentatively identified as Rydberg transitions of ultra highly excitation (UHE) metal lines. This UHE phenomenon is known for almost three decades, yet no satisfying answer has been found. In this talk I will present recent progress on UHE white dwarfs that was made thanks to Gaia, photometric surveys like TESS or ZTF, dedicated spectroscopic and spectropolarimetric follow-up, and discuss open questions.

DAHe stars have active chromospheres

N. Walters[1]

[1] *Department of Physics and Astronomy, University College London, London, UK*

Despite thousands of spectroscopically-identified white dwarfs, two years ago only one isolated and cool star was known to exhibit Balmer emission. Six such systems are now known, suggesting a new class of chromospherically-active white dwarfs. Furthermore, their close grouping on the HR diagram points to a single star evolutionary origin, but with an unknown source of chromospheric heating. The common characteristics of the class are important pieces of the puzzle and include apparent isolation, fast rotation, and magnetism. In this talk, we report photometric, spectroscopic, and spectropolarimetric observations of the class prototype, GD 356, where the data point to a temperature inversion similar to that seen in the Sun and cool dwarf stars. Despite the unknown physics, there are several testable predictions if the emission has an intrinsic origin. Further observations are crucial to constrain any evolution-activated chromospheric phenomena, with implications for not only this whole class of stellar remnants, but for magnetic stars in general.

Emerging thoughts on the new class of DAHe white dwarfs

J. J. Hermes, et al.

Boston University

The DAHe white dwarfs are a remarkable new class of variables that exhibit strong magnetism, Balmer-line emission, as well as spectral and photometric variability, with periods most commonly shorter than 3 hr. Since the announcement of the second DAHe at the last European White Dwarf Workshop in 2018, we now know of at least eight DAHe. The known DAHe have remarkably similar atmospheric parameters, with effective temperatures between 7500-8600 K and masses between 0.56-0.83 solar masses. I will update observational progress on the search for new DAHe, and observational trends in these strange objects which defy simple explanation.

Prediction and assignment of spectra from strongly magnetized White Dwarf stars using high-accuracy quantum chemistry

Stella Stopkowicz

Universität Mainz, Department Chemie, Duesbergweg 10-14, 55128 Mainz

Observational spectra from stellar objects allow insight about the composition of their atmospheres. In many cases the absorption lines in the recorded spectra can be assigned using accurate experimental data for the species in question. Such assignments, however, become significantly more complicated or even impossible - when strong magnetic fields are involved. For example, on magnetic White Dwarf (WD) stars magnetic fields of up to about 1000 MG are encountered. On the other hand, on Earth, only up to 1 MG can be generated in specialized high-field labs. Hence, predictions can often not be made by experimental means. In such cases, high-level quantum-chemical predictions are useful for the assignment of absorption lines in respective magnetic WD spectra. Because the magnetic and Coulomb forces are equally important, they need to be treated on an equal footing.This is possible when finite-field quantum-chemical methods are employed. The development of finite-field Coupled-Cluster[1] (CC) and Equation-of-Motion CC methods[2−5] has enabled such predictions for systems with more than just a couple of electrons. In this contribution we will discuss how respective accurate and reliable predictions are made and present a recent successful assignment of an observational spectrum from a strongly magnetized WD star, through a fruitful interplay between astrophysics and quantum chemistry. The assignment involves the identification of metals in the atmosphere and an estimate of the strength of its magnetic field.[6]

1. S. Stopkowicz, J. Gauss, K. K. Lange, E. I. Tellgren, and T. Helgaker, J. Chem. Phys. 143, 074110 (2015)
2. F. Hampe and S. Stopkowicz, J. Chem. Phys. 146, 154105 (2017)
3. F. Hampe and S. Stopkowicz, J. Chem. Theory Comput. 15, 4036 (2019)
4. F. Hampe, N. Gross, and S. Stopkowicz, Phys. Chem. Chem. Phys. 22, 23522 (2020)
5. M.-P. Kitsaras, L. Grazioli, and S. Stopkowicz, in prep. 2022
6. M. Hollands, S. Stopkowicz, J.J. Hermes, M.-P. Kitsaras, F. Hampe, S. Blaschke, B. Gänsicke, in prep. 2022

Evidence that all DQ stars are binary / merger products

J. Farihi

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

There are now several independent lines of evidence that all DQ white dwarfs are the products of binary evolution or analogous mergers. 1) Post-common envelope binaries with a white dwarf and a main-sequence star are common, and while helium-rich DB and DC stars exist within this population, not one in over 3000 systems hosts a DQ star. This implies that any companions to DQ progenitors either never encountered the RGB or AGB envelopes, or were devoured during these evolutionary phases. 2) The classical DQ stars appear to be somewhat less massive than their DA counterparts, with a handful of compelling low-mass examples; together with their thin helium envelopes, these facts suggest a moderate or strong binary influence during their evolution. 3) Although challenging to measure due to the lack of atomic lines, DQ stars may be magnetic more often than their non-DQ counterparts, with a few examples of rapid rotation. 4) The nearest and well-studied DQ white dwarf Procyon B is understood to be inconsistent with single star evolution. 5) Lastly, DQ stars cannot be descended from either DA or DB white dwarfs that exhibit well-documented evidence for planetary debris and pollution over a significant fraction of their cooling ages. In stark contrast, the DQ pollution frequency is distinctly stunted, they have never been observed to have an infrared excess, and when detected, their metal abundances are 1000 times smaller than other polluted white dwarfs with similar cooling ages. The actual evolutionary pathway to DQ stars will require further stellar and binary evolution modeling, and investigations should consider relatively mundane possibilities such as the cannibalization of giant planets or low-mass stellar companions.

Massive White Dwarfs from Nearby Young Clusters

David R. Miller[1], Ilaria Caiazzo[2], Jeremy Heyl[1], Harvey B. Richer[1], and Pier-Emmanuel Tremblay[3]

[1] *Department of Physics and Astronomy, University of British Columbia, Vancouver, BC V6T 1Z1, Canada*
[2] *TAPIR, Walter Burke Institute for Theoretical Physics, Caltech, Pasadena, CA 91125, USA*
[3] *Department of Physics, University of Warwick, Coventry, CV4 7AL, UK*

Extensive searches for WDs in open star clusters have left a dearth in the high mass region of the WD initial-final mass relation. In an attempt to address this issue we developed a technique to identify WDs that were born in and subsequently escaped from nearby young open clusters. We applied this technique to all of the clusters younger than 200 Myr and within 200 pc of the Sun. From this search we identified five candidate escaped WDs in the Alpha Persei cluster, as well as three escapee candidates and one new current member in the Pleiades. We obtained spectra for all eight WDs and were able to confirm that six are massive WDs sufficiently young to have originated in their respective clusters. The three in Alpha Persei, in particular, are each more massive than any WD previously associated with a cluster using Gaia astrometry, and possess some of the most massive progenitors.

Search for new variable Extremely-low mass white dwarf stars

Larissa Antunes Amaral[1], Maja Vuckovic[1], and Ingrid Pelisoli[2]

[1] *Instituto de Física y Astronomía, Universidad de Valparaíso, Gran Bretaña 1111, Playa Ancha, Valparaíso 2360102, Chile*
[2] *Department of Physics, University of Warwick, Gibbet Hill Road, Coventry, CV4 7AL, UK*

The Galaxy is not old enough to form a 0.3Msun white dwarf by a single star evolution. Yet, about a hundred of these extremely-low mass white dwarfs (ELMs) are known. If these stars are part of a binary system, their existence could be explained as a result of mass transfer in a post-main-sequence common-envelope phase or a stable Roche-lobe overflow episode in multiple systems. The recent discovery of pulsating ELMs (ELMVs) has greatly sparked the interest in these objects, as it provides a unique opportunity to explore the internal structure and shed a light on their formation. As strong sources of gravitational waves, ELMs will also have an important contribution to the signal detected by space-based missions such as LISA. Furthermore, current observations with TESS satellite and Gaia Mission are an important asset as they allow a compilation of an all-sky volume-limited sample of ELM candidates with measured distances. Also, TESS is playing an important role in the characterization of new variable white dwarfs. Last year, we performed ground-based follow-up observations of the variable ELM candidates, both pulsating and binaries, from TESS light curves, as well as the high-probability ELMVs that were selected from the Gaia sample. In this talk, I will present the new ELM candidates that we selected based on their variability in TESS data and the results that we are obtaining from ground-based photometric and spectroscopic follow-up.

Exploring the internal rotation of the extremely low-mass white-dwarf star GD 278 with TESS asteroseismology

Leila M. Calcaferro[1,2], Alejandro H. Córsico[1,2], Leandro G. Althaus[1,2]

[1] *Grupo de Evolución Estelar y Pulsaciones, Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, Paseo del Bosque s/n, 1900, La Plata, Argentina*
[2] *Instituto de Astrofísica La Plata, CONICET-UNLP, Paseo del Bosque s/n, 1900, La Plata, Argentina*

Following the discovery of pulsations in GD 278 and the identification of possible rotational splittings (Lopez et al. 2021), the first ones in an extremely low-mass white-dwarf obtained by the Transiting Exoplanet Survey Satellite (TESS), we carried out an asteroseismological exploration to probe its internal rotational properties. We will show the first results of employing an asteroseismological model that closely matches the observed periods of this star.

Ensemble asteroseismology of blue-edge ZZ Cetis using , the mighty white dwarf code

S. Reece Boston, Charles R. Evans, J. Christopher Clemens

Department of Physics and Astronomy, University of North Carolina

With the success of the GAIA survey, and the advances in space-based photometry from K2 and TESS, the field of white dwarf (WD) asteroseismology has a rich pool of highly-accurate observations to draw upon. To facilitate faster and more adaptable WD models, we have developed , a parametric modeling code for WD asteroseismology. uses parametrized element distributions and modular equations of state. The parametrized element distributions allow skipping gigayears of stellar evolution to arrive at the WD stage. The modular equation of state uses analytic equations with exact derivatives, avoiding numerical noise caused by finite differencing or tabular interpolation. This leads to smooth profiles in all quantities, including the Brunt-Väisälä frequency. models are easily adaptable, run quickly, and produce high numerical accuracy. In this talk we will describe the models and the application of to understand the pulsation properties of the blue-edge ZZ Ceti white dwarfs. We will present a set of models that reproduce the $l = 1$ and $l = 2$ modes for the entire ensemble of stars, illustrating the role of canonically thick vs thin H layers and revealing the role of total mass in establishing both H and He layer thickness during the late stages of stellar evolution.

Pulsating White dwarfs with hydrogen-rich atmospheres

Alejandra D. Romero, S. O. Kepler, Larissa Antunes Amaral, Gabriela Oliveira da Rosa

Physics Institute, Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves 9500, Brazil

The most numerous class of pulsating white dwarfs is that known as ZZ Cetis or DAV. The instability strip is located between $\sim$ 13 000 K and 10 500K, depending on the stellar mass. These objects show photometric variations with periods between 70 and 2000 s, and amplitudes up to 0.3 mag, corresponding to spheroidal non-radial gravity modes with low harmonic degree. The number of known DA white dwarfs, and thus of DA pulsators, dramatically increased with the SDSS and the effort of several authors conducting ground-based observations and even more with space-based observations form the *Kepler* and *TESS* satellites. Currently there are around 500 known ZZ Ceti stars. In this work we present the new ZZ Cetis discovered from the data obtained by the Transiting Exoplanet Survey Satellite (TESS) mission, from Sectors 1 to 50, observed with 120 s- and 20 s-cadence. Our sample likely includes 13 low-mass and one extremely low-mass white dwarf candidate, considering the mass determinations from fitting Gaia magnitudes and parallax.

GW Vir instability strip in the light of new observations of PG 1159 stars

Paulina Sowicka[1], Gerald Handler[1], David Jones[2,3] et al.

[1]*Nicolaus Copernicus Astronomical Center, Polish Academy of Sciences, Warszawa, Poland*
[2]*Instituto de Astrofísica de Canarias, E-38205 La Laguna, Spain*
[3]*Departamento de Astrofísica, Universidad de La Laguna, E-38206 La Laguna, Spain*

The first of the three classical instability strips of white dwarf pulsators, the GW Vir strip, contains stars of PG 1159 and [WC] spectral types. These hot and compact PG 1159 stars (H-deficient, He-/C-/O-rich) are thought to be formed as a result of a "born-again" episode: either a very late thermal pulse experienced by a hot white dwarf during its early cooling phase, or a late thermal pulse that occurs during the post-AGB evolution when H burning is still active. This evolutionary history is reflected in their chemical abundances. In contrast to the purity of the DAV and DBV instability strips, only some 30% of the stars in the GW Vir domain pulsate. Consequently, the DA and DB pulsators are otherwise normal white dwarfs and their interiors represent the interiors of all white dwarfs, which is not the case for the PG 1159 stars. While several explanations for this discrepancy have been proposed, the case of nitrogen is particularly interesting. There is an observed nitrogen dichotomy: N-rich stars are pulsators, whereas N-poor stars are all nonpulsators, with one culprit: N-rich nonpulsator PG 1144+005. With our discovery of pulsations in PG 1144+005 the current picture appears complete, but is based on a small number of objects, as only 14 out of 55 PG 1159 stars have both information about variability as well as the nitrogen abundance. I will present the results of our survey of PG 1159 stars and discuss their implications.

Pulsating hydrogen-deficient white dwarfs and pre-white dwarfs observed with TESS: Discovery of new GW Vir stars

Murat Uzundag[1,2] Alejandro H. Córsico[3] S. O. Kepler[4] Leandro G. Althaus[3] Klaus Werner[5] Nicole Reindl[6] Keaton J. Bell[7] Michael Higgins[8] Gabriela O. da Rosa[4] Maja Vučković[1] Alina Istrate[9]

1. *Instituto de Física y Astronomía, Universidad de Valparaíso, Gran Bretaña 1111, Playa Ancha, Valparaíso 2360102, Chile*
2. *European Southern Observatory, Alonso de Cordova 3107, Santiago, Chile*
3. *Grupo de Evolución Estelar y Pulsaciones. Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, Paseo del Bosque s/n, 1900 La Plata, Argentina*
4. *Instituto de Física, Universidade Federal do Rio Grande do Sul, 91501-970, Porto-Alegre, RS, Brazil*
5. *Institut für Astronomie und Astrophysik, Kepler Center for Astro and Particle Physics, Eberhard Karls Universität, Sand 1,72076 Tübingen, Germany*
6. *Institute for Physics and Astronomy, University of Potsdam, Karl-Liebknecht-Str. 24/25, D-14476 Potsdam, Germany* 7. *DIRAC Institute, Department of Astronomy, University of Washington, Seattle, WA-98195, USA*
8. *Department of Physics, Duke University, Durham, NC-27708, USA*
9. *Department of Astrophysics/IMAPP, Radboud University, P O Box 9010, NL-6500 GL Nijmegen, The Netherlands*

With the advance of high precision and high duty cycle photometric monitoring from the Transiting Exoplanet Survey Satellite (TESS), unprecedented asteroseismic measurements and tools have become available for pulsating white dwarfs and pre-white dwarfs. In this project, we aim at searching for the hydrogen -deficient pulsating pre-white dwarf stars called GW Vir stars that exhibit atmospheres rich in carbon, oxygen and helium. We processed and analyzed the high-precision TESS photometric light curves of the four target stars, and derived their oscillation frequencies. For each of these TESS targets, we obtained low-resolution spectra and fitted model atmospheres in order to derive their fundamental atmospheric parameters. We performed an asteroseismological analysis of these stars on the basis of PG 1159 evolutionary models that take into account the complete evolution of the progenitor stars. We searched for patterns of uniform period spacings in order to constrain the stellar mass of the stars, and employed the individual observed periods to search for a representative seismological model. Using the high-quality data collected by the TESS space mission and follow-up spectroscopy, we have been able to discover and characterize new GW Vir stars. In this proceeding, I will give a brief overview of the current state-of-the-art analysis of GW Vir stars from the perspective of the recent space missions.

Seismology of accreting white dwarfs

Praphull Kumar and Dean Townsley

The University of Alabama, Tuscaloosa, Alabama, USA

Accreting white dwarfs in Cataclysmic variables (CVs) show short-period (tens of minutes) brightness variations that are consistent with non-radial oscillations similar to those observed in isolated white dwarfs (WDs), known as ZZ Ceti type stars. GW Librae, a dwarf nova, was the first CV in which non-radial oscillations were observed and continues to be the best studied accreting WD displaying these pulsations. These oscillations are thought to be gravity modes (g-modes) based on their periods and similarity to g-modes in isolated WDs. Unlike is observed for isolated WDs, accreting WDs are rotating rapidly, with spin periods comparable to or shorter than typical low-order oscillation frequencies. The relationship between the interior temperature and surface temperature is also different from that in isolated WDs due to the accretion. The surface temperature of an accreting WD is observed to vary significantly on a months to year timescale between dwarf novae accretion events, providing an interesting opportunity to study how this temperature change effects g-mode behavior. In this talk, I will show results from adiabatic seismological calculations for accreting WDs, focusing on low-order ($\ell = 1$) modes including how they vary in response to temperature changes in the subsurface layers due to a dwarf nova accretion event. These calculations include rotation non-perturbatively, as required by the high spin rate. I will discuss the thermal history of these accreting WDs, and compare the seismological properties with and without rotation. Comparison of g-mode frequencies to observed objects may allow inference of features of the internal structure of the WDs such as masses, surface abundance, accretion history, and more. The variation of mode frequencies during cooling after outburst provides a novel method of identifying modes.

MESA Models of WD Cooling with C/O Phase Separation

Evan Bauer

Center for Astrophysics | Harvard & Smithsonian, 60 Garden St, Cambridge, MA 02138, USA

I will describe the recent implementation of C/O phase separation for crystallizing white dwarf models in the MESA stellar evolution code. In combination with the Skye equation of state that MESA uses for WD interiors, this implementation allows unprecedented thermodynamic consistency in evaluating the energetics associated with WD crystallization, including terms for both latent heat and mixing of C/O in the liquid mantle surrounding the solid WD core. I will show some comparisons of cooling delays in MESA models and other WD codes that include phase separation. I will then discuss some of the subtleties associated with including both C/O phase separation and other potential sources of WD cooling delays such as ^{22}Ne sedimentation in the same model, and touch on some implications for WD populations that seem to experience long cooling delays associated with crystallization such as the WD Q-branch and the open cluster NGC 6791.

Ultra-massive white dwarf models

Maria Camisassa [1]

[1] *Department of Applied Mathematics, University of Colorado, Boulder, CO 80309-0526, USA.*

Ultra-massive white dwarfs ($1.05M_\odot > M_{WD}$) are particularly interesting objects that allow us to study extreme astrophysical phenomena such as type Ia supernovae and micronovae explosions and merger events. Despite the large interest in ultra-massive white dwarfs, there is not a clear consensus in the literature whether these stars harbour oxygen-neon (ONe) or carbon-oxygen (CO) cores. In addition, the new observations provided by the ESA *Gaia* space mission indicate that a fraction of the ultra-massive white dwarfs experience a strong delay in their cooling, which cannot be attributed only to the occurrence of crystallization, thus requiring an unknown energy source able to prolong their life for long periods of time. This phenomenon, reflected both in their kinematic and photometric properties, is known as "the cooling anomaly of ultra-massive white dwarfs". In this talk I present detailed ultra-massive white dwarf models both for CO and ONe core-chemical composition, that consider realistic chemical profiles and all the relevant energy sources that control their evolution, such as latent heat and phase separation due to crystallization and ^{22}Ne sedimentation. We show that the energy released by ^{22}Ne sedimentation in the deep interior of ultra-massive white dwarfs with CO cores is in line with the long cooling delay of these stellar remnants. I will also briefly describe other possible solutions to the "cooling anomaly of ultra-massive white dwarfs".

Improving Ages of Individual White Dwarfs

E.J. Jeffery[1], T. von Hippel[2], E. Robinson[2], D.A. van Dyk[3], D.C. Stenning[3]

[1] *California Polytechnic State University, San Luis Obispo;* [2] *Embry-Riddle Aeronautical University;* [3] *University College London;* [4] *Simon Fraser University*

White dwarfs are an important chronometer for measuring the ages of stellar populations. By combining high precision parallaxes from Gaia and photometry from surveys such as Pan-STARRS and SDSS, we apply a sophisticated Bayesian algorithm to determine ages and other fundamental properties for individual white dwarfs. To improve and calibrate our methods, we apply our technique to known white dwarfs in open clusters, as well as a subset of well-studied DA field white dwarfs. With an eye towards our ultimate goal of applying this technique to every white dwarf in the Gaia catalog, these tests provide important understanding of any systematics that arise when using different filter sets, model sets, etc.

Structure and evolution of massive white dwarfs in general relativity

Leandro G. Althaus[1,2], María E. Camisassa[3], Santiago Torres[4,5], Tiara Battich[6], Alejandro H. Córsico[1,2], Alberto Rebassa-Mansergas[4,5], Roberto Raddi[4,5]

[1] *Grupo de Evolución Estelar y Pulsaciones. Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, Paseo del Bosque s/n, 1900 La Plata, Argentina*
[2] *CCT - CONICET*
[3] *Applied Mathematics Department, University of Colorado, Boulder, CO 80309-0526, USA*
[4] *Departament de Física, Universitat Politècnica de Catalunya, c/Esteve Terrades 5, 08860 Castelldefels, Spain*
[5] *Institute for Space Studies of Catalonia, c/Gran Capita 2–4, Edif. Nexus 104, 08034 Barcelona, Spain*
[6] *Max-Planck-Institut für Astrophysics, Karl-Schwarzschild-Strasse 1, D-85748, Garching bei München, Germany*

Ultra-massive white dwarfs ($M > 1.10M_\odot$) are of utmost importance in view of the role they play in type Ia supernovae explosions, merger events, the existence of high magnetic field, and the physical processes in the Super Asymptotic Giant Branch (SAGB) phase. We present a set of constant rest-mass ultra-massive oxygen/neon (O/Ne) white dwarf cooling tracks with masses above $M > 1.29M_\odot$ which fully take into account the effects of general relativity on the structural and evolutionary properties of the evolving white dwarfs. The sequences has been calculated with the La Plata stellar evolution code, `LPCODE`, which has been modified to fully include the effects of general relativity. For comparison purposes, the same sequences have been computed but for the Newtonian case. We find, as expected, that the importance of general relativistic effects increases as the stellar mass is increased. For the most massive white dwarfs, the resulting stellar radius is markedly smaller in the case where general relativity effects are taken into account. Also, the evolutionary properties of the most massive white dwarfs are strongly modified. In particular, the cooling time for our most massive white dwarf sequence results in about a factor of two smaller than in the Newtonian case at advanced stages of evolution. Finally, we find that chemical distribution due to phase separation on crystallization causes O/Ne white dwarfs with stellar masses larger than $1.36M_\odot$ to become gravitationally unstable against general relativity effect, leading to a self-induced thermonuclear supernovae. We conclude that in the case of most massive white dwarfs, general relativity effects should be taken into account for an accurate assessment of the structural and evolutionary properties of these stars. These new models of ultra-massive white dwarfs constitute an improvement over those computed in the framework of the standard Newtonian theory of stellar interiors.

Tidal deformability of crystallized white dwarfs in full general relativity

L. Perot, N. Chamel

Universit Libre de Bruxelles, Belgium

Space-based gravitational-wave detectors offer new prospects for probing the interior of white dwarfs in binary systems through the imprints of tidal effects on the gravitational-wave signal. Some of the binaries that will be observed could have evolved for long enough for the white dwarfs to be at least partially crystallized. The apsidal motion constant k_2 (also called the second gravitoelectric Love number) of a cold crystallized white dwarf was computed in full general relativity considering different compositions. The elasticity of the crystallized core was found to systematically reduce the tidal deformability, especially for low-mass stars. Fully relativistic results were compared to those obtained in Newtonian gravity. It was shown that the relativistic correction to the observable tidal deformability $k_2 R^5$ (where R is the stellar radius) is negligible for low-mass white dwarfs but becomes increasingly important for more massive white dwarfs. When approaching the maximum mass, the application of Newtonian theory instead of general relativity leads to dramatic errors. The case of eccentric binaries, for which the precession of the periastron causes a frequency splitting of the gravitational-wave signal depending on the apsidal motion constants of the two stars, was investigated. Future measurements of the precession rate by the Laser Interferometer Space Antenna, which is planned to be in operation within the next decade, could potentially provide estimates of the individual masses. It was found that the errors incurred by the neglect of the elasticity of the crystallized core could be very large, especially for low-mass white dwarfs. Gravitational-wave observations could thus provide a new way to study the crystallization of white dwarfs.

Recent progress on the modelling of crystallizing white dwarfs

Simon Blouin

Department of Physics and Astronomy, University of Victoria, Canada

The exquisite *Gaia* astrometry has recently opened up the possibility of testing our understanding of white dwarf evolution in unprecedented details. In particular, the signature of core crystallization in the *Gaia* HR diagram informs us on the magnitude of the cooling delay induced by the release of latent heat and by chemical fractionation processes taking place during this phase transition. Remarkably large discrepancies with theoretical models have been identified, stimulating a flurry of modelling efforts over the past few years. In this talk, I will discuss the two main sources of uncertainty for the modelling of core crystallization: (1) the microphysics of chemical fractionation and (2) the initial core composition profile at the beginning of the white dwarf cooling track. I will first present our recent work on dense plasmas phase diagrams and how the "distillation" of ^{22}Ne can explain the recent observational puzzles. I will then discuss our ongoing efforts to determine the efficiency of convective boundary mixing in red giant stars using large-scale high-resolution 3D hydrodynamics simulations with the goal of better constraining the core composition of white dwarfs.

Crystallization dynamos: slow convection and fast rotation

Sivan Ginzburg[1], Jim Fuller[1], Adela Kawka[2], Ilaria Caiazzo[1]

[1] *TAPIR, California Institute of Technology, Pasadena, CA, USA*
[2] *International Centre for Radio Astronomy Research, Curtin University, Perth, WA, Australia*

It has been recently suggested that white dwarfs generate magnetic fields in a process analogous to the Earth. The crystallization of the core creates a compositional inversion that drives convection, and combined with rotation, this can sustain a magnetic dynamo. We reanalyse the dynamo mechanism, arising from the slow crystallization of the core, and find convective turnover times $t_{\rm conv}$ of weeks to months – longer by orders of magnitude than previously thought. With white dwarf spin periods $P \ll t_{\rm conv}$, crystallization-driven dynamos are almost always in the fast rotating regime, where the magnetic field B is at least in equipartition with the convective motion and is possibly further enhanced by a factor of $B \propto (t_{\rm conv}/P)^{1/2}$, depending on the assumed dynamo scaling law. We track the growth of the crystallized core using MESA and compute the magnetic field $B(T_{\rm eff})$ as a function of the white dwarf's effective temperature $T_{\rm eff}$. We compare this prediction with observations and show that crystallization-driven dynamos can explain some – but not all – of the $\sim$MG magnetic fields measured for single white dwarfs, as well as the stronger fields measured for white dwarfs in cataclysmic variables, which were spun up by mass accretion to short P. Our $B(T_{\rm eff})$ curves might also explain the clustering of white dwarfs with Balmer emission lines around $T_{\rm eff} \approx 7500$ K.

Improving the Physics of Mixing During Phase Separation in Crystallizing White Dwarf Stars

M. H. Montgomery[1] & B. H. Dunlap[1]

[1] *University of Texas and McDonald Observatory, Austin, TX, USA*

Crystallization has important consequences for the evolution and pulsation of white dwarf stars. Similarly, the associated process of phase separation—the partial separation of carbon and oxygen during core crystallization—also affects white dwarf cooling and pulsation since it changes the amount of gravitational energy released as well as the extent of the crystallized core. We propose a new prescription for fluid mixing during phase separation that we claim is more physical. This prescription has a non-negligible effect on the gravitational energy released and a strong effect on the properties of g-mode oscillations in these stars. In agreement with recent results, we find that any magnetic fields generated during mixing should be undetectable.

New Evolutionary Channel of Magnetic White Dwarfs?

D. Korčáková[1], F. Sestito[2], N. Manset[3], P. Kroupa[1,4], V. Votruba[5], M. Šlechta[6], N. Dvořáková[1], A. Raj[7], and S. D. Chojnowski[8]

[1] *Charles University, Faculty of Mathematics and Physics, Astronomical Institute, V Holešovičkách 2, 180 00 Praha 8, Czech Republic;* `kor@sirrah.troja.mff.cuni.cz`
[2] *Department of Physics and Astronomy, University of Victoria, Victoria, BC, V8W 3P2, Canada*
[3] *Canada-France-Hawaii Telescope Corporation, 65-1238 Mamalahoa Hwy, Kamuela HI 96743*
[4] *Helmholtz-Institut für Strahlen- und Kernphysik, University of Bonn, Nussallee 14-16, D-53115 Bonn, Germany*
[5] *Institute of Theoretical Physics and Astrophysics, Masaryk University, 611 37 Brno, Kotlářská 2, Czech Republic*
[6] *Astronomical Institute of the Academy of Science of the Czech Republic, Fričova 298, 251 65 Ondřejov, Czech Republic*
[7] *Department of Physics and Astrophysics, University of Delhi, Delhi 110007, India*
[8] *Department of Physics, Montana State University, P.O. Box 173840, Bozeman, MT 59717–3840, USA*

The origin of strong magnetic fields in white dwarfs has not been satisfactorily explained yet. During the formation of a white dwarf, the magnetic field is amplified. However, a strong magnetic field may also be generated during a merger, the accretion of rocky debris may also contribute, and the crystallisation process may also play a role. Each of these theories has its drawbacks. What if, in fact, a combination of several phenomena plays a role? One clue may be found in FS CMa stars. Recently, we discovered a very strong magnetic field in IRAS 17449+2320. The magnetic field modulus reaches 6.2 ± 0.2 kG, which is of the order of the strongest magnetic field found in Ap stars. The properties of IRAS 17449+2320 indicate that this object is a post-merger system. Its position on the Hertzsprung-Russell diagram is near the terminal main sequence, as any other FS CMa star. This discovery opens the possibility that progenitors of magnetically strong white dwarfs are hidden among FS CMa stars.

The origin and evolution of strong magnetic fields in white dwarfs

Matthias R. Schreiber & Diogo Belloni

Universidad Tecnica Federico Santa Maria

White dwarfs have been speculated to potentially have strong magnetic fields (exceeding 1 MG) since 1947, but the first detection of a magnetic field in a white dwarf was only obtained more than twenty years later. Ever since, the question why some white dwarfs become strongly magnetic while others do not, has been one of the fundamental unsolved issues of stellar evolution.

Throughout the decades, several theories have been suggested for the magnetic field generation in white dwarfs but the fossil field, the double degenerate merger, and the common envelope dynamo scenarios all fail when confronted with the observed incidence of magnetic fields in single white dwarfs and white dwarfs in binaries.

We suggest that instead a rotation and crystallization driven dynamo similar to those operating in planets and low mass stars is responsible for a large fraction of the observed strongly magnetic white dwarfs (Schreiber et al. 2021, Nature Astronomy, 5, 648). We show that this new scenario can explain the absence of bright intermediate polars in globular clusters, the accumulation of magnetic white dwarfs among metal polluted white dwarfs, the occurrence rate of strong magnetic fields in double white dwarf binaries, and why a large fraction of Cataclysmic Variables but only a small part of their detached progenitor systems contain a strongly magnetic white dwarf.

We conclude that a crystallization and rotation driven dynamo most likely plays a mayor role in the magnetic field generation in white dwarfs.

The White Dwarf Binary Pathways Survey

Steven Parsons

The University of Sheffield

Close binaries containing at least one white dwarf are thought to be the progenitors of some of the Galaxy's most exotic objects, such as cataclysmic variables, AM CVn binaries, hot subdwarf stars, double degenerates and thermonuclear supernovae. This zoo of possible evolutionary outcomes demonstrates the complexity of trying to study the population of white dwarf binaries as a whole. However, without a detailed understanding of the evolution of white dwarf binaries, we will remain unable to unravel the pathways towards thermonuclear supernovae and the conditions under which they ignite, and equally, we will not be able to accurately predict or model the low-frequency gravitational background from galactic white dwarf binaries. We began the the white dwarf binary pathways survey to take a step back in time to the last stage at which all of these systems were part of the same population of detached white dwarf plus main-sequence star binaries. The properties of these binaries can reveal their past evolution and measure how common different evolutionary channels are. In this talk a I will give an update on the progress of this project, including new results from Hubble Space Telescope observations, which reveal a number of systems with very low mass white dwarfs as well as the discovery of long period systems. I will also discuss contamination of the survey from active stars and how Gaia can be used to make far cleaner selections of these types of binaries.

Double white dwarf separation distribution: astrometric evidence from GAIA for a gap at 1 AU

Valeriya Korol[1], Vasily Belokurov[2,3] and Silvia Toonen[1,4]

[1]Institute for Gravitational Wave Astronomy & School of Physics and Astronomy, University of Birmingham, Birmingham, B15 2TT, UK
[2]Institute of Astronomy, Madingley Rd, Cambridge, CB3 0HA
[3]Center for Computational Astrophysics, Flatiron Institute, 162 5th Avenue, New York, NY 10010, USA
[4]Anton Pannekoek Institute for Astronomy, University of Amsterdam, 1090 GE Amsterdam, The Netherlands

Characterising the Galactic DWD population has proven to be technically challenging. Even with a sample now amounting to around 150 binaries, our knowledge of the physical characteristics of the DWD population remains rudimentary. Gaia offers an opportunity to identify unresolved DWD systems in bulk, significantly boosting our statistics. This is possible because the trajectory of the centre of light of an unresolved binary is different from that of its centre of mass. Binary-induced stellar centroid wobbling can therefore be detected as an excess in the goodness-of-fit of the single-star astrometric model, and the wobble amplitude can be related to the separation. In this way we can access orbital separations between approximately 0.01 and 2 au, where theoretical models predict a gap in the DWD separation distribution caused by the common envelope phase(s) prior to DWD formation. In this talk I will discuss the formation of this gap from a theoretical perspective and will discuss the comparison between the models and Gaia data.

Measuring the initial-final mass relation using wide binaries

Mark Hollands, Stuart Littlefair, Steven Parsons

The University of Sheffield

The white dwarf Initial-Final Mass-Relation (IFMR) is an important ingredient in understanding stellar evolution from start to finish, but cannot easily modelled. However, the IFMR can be empirically determined in a number of ways, with white dwarfs in open clusters historically the most common approach. More recently, binaries containing white dwarfs have also been used to constrain the IFMR, under the assumption that both components have the same total age. We have observed 58 wide double white dwarf (DWDs) binaries with FORS2, sampling a wide range of T_{eff} and $\log g$. With precisely measured stellar parameters for both components, we expand upon the Bayesian framework introduced by Andrews et. al. (2015) to determine a multi-segment IFMR covering initial masses of 1–8 $M_{\odot}$. To our surprise, 46 percent of our observed DA-DA pairs have irreconcilable stellar parameters and thus cannot have evolved together without having undergone other interactions, such as mergers.

Improved Constraints on the Initial-to-Final Mass Relation of White Dwarfs using Wide Binaries

Manuel Barrientos & Julio Chanamé

Physics and Astronomy, University of Oklahoma, 440 W. Brooks St., Norman, OK, 73019 USA

We present observational constraints for the initial-to-final mass relation (IFMR) derived from 11 white dwarfs (WDs) in wide binaries (WBs) that contain a turnoff/subgiant primary. Because the components of WBs are coeval to a good approximation, the age of the WD progenitor can be determined from the study of its wide companion. However, previous works that used WBs to constrain the IFMR suffered from large uncertainties in the initial masses because their MS primaries are difficult to age-date with good precision. Our selection of WBs with slightly evolved primaries avoids this problem by restricting to a region of parameter space where isochrone ages are significantly easier to determine with precision. The WDs of two of our originally selected binaries were found to be close double degenerates, and are not used in the IFMR analysis. We obtained more precise constraints than existing ones in the mass range 1-2 $M_{\odot}$, corresponding to a previously poorly constrained region of the IFMR. Having introduced the use of turnoff/subgiant-WD binaries, the study of the IFMR is not limited anymore by the precision in initial mass, but now the pressure is on final mass, i.e., the mass of the WD today. Looking at the full dataset, our results would suggest a relatively large dispersion in the IFMR at low initial masses. More precise determinations of the mass of the WD components of our targets are necessary for settling this question.

Testing White Dwarf Age Estimates using Wide Double White Dwarf Binaries from Gaia EDR3

Tyler Heintz[1], J.J. Hermes[1], Kareem El-Badry[2], Charlie Walsh[1], Jennifer L. van Saders[3], C.E. Fields[4], and Detlev Koester[5]

[1]*Department of Astronomy & Institute for Astrophysical Research, Boston University,* [2]*Center for Astrophysics - Harvard & Smithsonian,* [3]*Institute for Astronomy, University of Hawaii,* [4]*Center for Theoretical Astrophysics, Los Alamos National Laboratory,* [5]*Institut für Theoretische Physik und Astrophysik, University of Kiel*

White dwarf stars evolve simply and predictably, making them reliable age indicators. However, self-consistent validation of the methods for determining white dwarf total ages has yet to be widely performed. Widely separated double white dwarf binaries are the perfect systems to test white dwarf total ages but only recently, with the launching of the Gaia mission, have large samples of these double white dwarfs been available. These double white dwarf systems can also provide insight into white dwarfs that experienced a merger in their past by making comparisons of their total ages. For such large samples of white dwarfs, spectroscopy is not readily available and thus most total age determinations rely on photometric data from all-sky surveys and must assume a spectral type of the white dwarf. In this talk, I will discuss recent work testing white dwarf total ages in large photometric samples using widely separated double white dwarfs from Gaia EDR3 as well as the implications of the results on the population of white dwarfs that have experienced a merger in their past.

White dwarf interactions in triple star systems

Abinaya Swaruba Rajamuthukumar[1], Adrian S. Hamers[1]

[1]*Max Planck Institute for Astrophysics, Garching*

The aim is to study the contribution of Type Ia Supernovae (SNe Ia) rates from triple systems containing white dwarfs. Since the rates from interactions in white dwarf binaries are thought to be insufficient to explain the SNe Ia rates, we think that it is important to study similar interactions in higher-order multiple star systems such as triple systems. We are particularly interested in the effect of tertiary star and the ratio of circular mergers to eccentric collisions in the formation of SNe Ia. We hope that this study will add input to the present understanding of SNe Ia and its progenitors.

An old triple system with an inner brown dwarf-white dwarf binary and an outer white dwarf companion

Alberto Rebassa-Mansergas, Siyi Xu, Roberto Raddi, Anna F. Pala, Enrique Solano, Santiago Torres, Francisco Jiménez-Esteban, Patricia Cruz

Departament de Física, Universitat Politècnica de Catalunya, c/ Esteve Terrades, 5, 08860 Castelldefels, Spain
Gemini Observatory/NSF's NOIRLab, 670 N. A'ohoku Place, Hilo, Hawaii, 96720, USA
European Space Agency, European Space Astronomy Centre, Camino Bajo del Castillo s/n, 28692 Villanueva de la Cañada, Madrid, Spain
Departmento de Astrofísica, Centro de Astrobiología (CSIC-INTA), ESAC Campus, Camino Bajo del Castillo s/n,
E-28692 Villanueva de la Cañada, Madrid, Spain

We identify the first inner brown dwarf-white dwarf binary of a hierarchical triple system in which the outer component is another white dwarf. From optical/near-infrared spectroscopy obtained at the Very Large Telescope with the X-Shooter instrument and/or from *Gaia* photometry plus SED fitting, we determine the effective temperatures and masses of the two white dwarfs and the effective temperature of the brown dwarf. By analysing the available *TESS* light curves of the inner unresolved binary we detect a signal at 1.04 days, which we interpret as the orbital period modulated from irradiation effects of the white dwarf on the brown dwarf's surface. Using the outer white dwarf as a cosmochronometer and analysing the kinematic properties of the system, we conclude that the triple system is about 10 Gyr old.

Searching for eclipsing double white dwarfs in TESS 200s full frame images

Emma T. Chickles[1] and Kevin B. Burdge[1]

[1]Kavli Institute for Astrophysics and Space Research, Massachusetts Institute of Technology, Cambridge, MA, USA

Close double white dwarfs undergoing orbital decay due to gravitational wave emission can be used to explore the white dwarf equation of state, tidal dissipation in white dwarfs, and are an important Type Ia supernovae progenitor channel. However, photometrically identifying these systems is challenging due to their narrow eclipses, meaning that even the best sampled ground-based lightcurves lack the sampling needed to identify many systems. In Cycle 5 of the *Transiting Exoplanet Survey Satellite* (TESS), which begins observations in September 2022, the full frame image (FFI) exposure time will be decreased from 600 seconds to 200 seconds. Lightcurves extracted from FFIs will have the temporal resolution needed to resolve the minute-long eclipses of double white dwarf systems, and will provide over ten thousand samples per sector, providing an unparalleled opportunity to study white dwarf variability with high time resolution. After extracting lightcurves for over one million white dwarf candidates, we will identify eclipsing white dwarf systems with a GPU-accelerated Box-Least-Squares period finding algorithm.

Evidence for a bi-modal distribution of post mass transfer systems?

F. Lagos,[1] M.R. Schreiber,[2,3] S.G. Parsons,[4] O. Toloza,[2,3] B.T. Gänsicke,[1] M.S. Hernandez,[3] L. Schmidtobreick,[5] D. Belloni[3]

[1] *Department of Physics, University of Warwick, Coventry, CV4 7AL, UK*
[2] *Millennium Nucleus for Planet Formation, NPF, Valparaíso, Chile*
[3] *Departamento de Física, Universidad Técnica Federico Santa María, Av. Espaa 1680, Valparaíso, Chile*
[4] *Department of Physics and Astronomy, University of Sheffield, Sheffield S3 7RH, UK*
[5] *European Southern Observatory (ESO), Alonso de Cordova 3107, Vitacura, Santiago, Chile*

Binary systems consisting of a white dwarf and a main-sequence companion with orbital periods up to ≈ 100 d are often thought to be formed through common envelope evolution which is still poorly understood. To provide new observational constraints on the physical processes involved in the formation of these objects, we are conducting a large-scale survey of close binaries consisting of a white dwarf and an A to K-type companion. Here we present three systems with eccentric orbits and orbital periods between $\approx 10 - 42$ d discovered by our survey. Based on *HST* spectroscopy and high angular resolution images obtained with SPHERE-IRDIS, we find that two of these systems are most likely triple systems while the remaining one could be either a binary or a hierarchical triple but none of them is a post common envelope binary (PCEB). The discovery of these systems shows that our survey is capable to detect systems with orbital periods of the order of weeks, but all six PCEBs we have previously discovered have periods below 2.5 d. We suggest that the fact that all of the systems we identify with periods of the order of weeks are not PCEBs indicates a transition between two different mechanisms responsible for the formation of very close ($\lesssim 10$ d) and somewhat wider WD+AFGK binaries: common envelope evolution and non-conservative stable mass transfer.

High-speed follow-up of eclipsing WD+dM binaries from ZTF

Alex Brown

Department of Physics and Astronomy, University of Sheffield, UK

Short-period binaries made up of a white dwarf and a low-mass main sequence star are the most typical product of the common-envelope phase. The compact nature of these post-common-envelope binaries means that a relatively large proportion are seen to eclipse, allowing for very precise constraints to be placed on the system parameters, making them ideal targets for testing stellar or evolutionary models. These systems are therefore excellent laboratories for studying more exotic classes of white dwarfs, where precise characterisation is key, as well as having the potential to provide much-needed insight into the relatively poorly understood common-envelope phase. With the prevalence of wide-field, time-domain photometric sky surveys, the number of eclipsing white dwarf + main sequence systems being discovered is increasing dramatically and so an efficient method to precisely and accurately measure the stellar and binary parameters for these systems will be vital to characterise the population as a whole as well as helping identify rare systems. This will become even more important in the LSST era, when thousands of these eclipsing binaries will be identified. In this talk, I will outline our photometric follow-up method as well as discussing our results so far, including the identification of a number of eclipsing magnetic white dwarfs, white dwarfs with brown dwarf companions, both hot and ultracool eclipsing white dwarfs, high and low mass white dwarfs, and the first ZZ Ceti in an eclipsing white dwarf + main sequence binary.

A bright, hot white dwarf with an M dwarf companion showing a large reflection effect

Veronika Schaffenroth[1], Nicole Reind[1], Dave Kilkenny[2], Brad Barlow[3]

[1] *Institute for Physics and Astronomy, University of Potsdam, Karl-Liebknecht-Str. 24/25, 14476 Potsdam, Germany*
[2] *Department of Physics & Astronomy, University of the Western Cape, Private Bag X17, Bellville 7535, South Africa*
[3] *Department of Physics, High Point University, One University Parkway, High Point, NC 27268, USA*

The reflection effect is a unique light variation observed when a hot, compact object, like a white dwarf or hot subdwarf, is orbited in a very close orbit by a cool, low mass main-sequence companion of similar or larger radius. Due to the short orbit all of those systems went through a previous common envelope phase. In the EREBOS (Eclipsing reflection effect binaries from optical surveys) project we were searching for more systems showing eclipses and a significant reflection effect. The majority of our systems have hot subdwarf primaries, only 4% of our discovered reflection effect binaries have white dwarf primaries. One of those is EC12250-3026, which is a totally eclipsing 17.6 mag hot DA with an M dwarf companion with a period of 0.1235 d only 450 pc away. The spectra show clear signs of emission lines in the hydrogen lines. We will present our first preliminary results on this interesting system.

An ultra-irradiated likely brown dwarf orbiting a white dwarf

Na'ama Hallakoun[1], Dan Maoz,[2] Alina G. Istrate,[3] Carles Badenes,[4] Elmé Breedt,[5] Boris T. Gänsicke,[6] Saurabh W. Jha,[7] Bruno Leibundgut,[8] Filippo Mannucci,[9] Thomas R. Marsh,[6] Gijs Nelemans,[3,10,11] Ferdinando Patat,[8] Alberto Rebassa-Mansergas[12,13] and Jason Spyromilio[8]

[1]*Department of particle physics and astrophysics, Weizmann Institute of Science, Rehovot 7610001, Israel*
[2]*School of Physics and Astronomy, Tel-Aviv University, Tel-Aviv 6997801, Israel*
[3]*Department of Astrophysics/IMAPP, Radboud University Nijmegen, PO Box 9010, 6500 GL Nijmegen, the Netherlands*
[4]*Department of Physics and Astronomy and Pittsburgh Particle Physics, Astrophysics and Cosmology Center (PITT PACC), University of Pittsburgh, 3941 O'Hara Street, Pittsburgh, PA 15260, USA*
[5]*Institute of Astronomy, Madingley Road, Cambridge CB3 0HA, UK*
[6]*Department of Physics, University of Warwick, Coventry CV4 7AL, UK*
[7]*Department of Physics and Astronomy, Rutgers, The State University of New Jersey, 136 Frelinghuysen Road, Piscataway, NJ 08854, USA*
[8]*European Southern Observatory, Karl-Schwarzschild-Straße 2, D-85748 Garching, Germany*
[9]*INAF – Osservatorio Astrofisico di Arcetri, Largo E. Fermi 5, I-50125, Firenze, Italy*
[10]*Institute for Astronomy, KU Leuven, Leuven, Belgium*
[11]*SRON, Netherlands Institute for Space Research, Sorbonnelaan 2, NL-3584 CA Utrecht, the Netherlands*
[12]*Departament de Física, Universitat Politècnica de Catalunya, c/Esteve Terrades 5, E-08860 Castelldefels, Spain*
[13]*Institut d'Estudis Espacials de Catalunya, Ed. Nexus-201, c/Gran Capità 2-4, E-08034 Barcelona, Spain*

Intense ultraviolet radiation plays an important role in a variety of astrophysical environments, from star-forming molecular gas clouds, through protoplanetary discs, to planetary atmospheres. This extreme radiation, that might lead to gas evaporation and to complete molecular dissociation, can significantly affect both stellar and planetary evolution. Irradiated substellar objects in very close orbits around hot and massive stars probe planetary atmospheres in this extreme and largely unexplored regime. However, their small sizes compared to their host stars greatly limit our ability to detect and study these systems. Irradiated substellar objects can be particularly revealing when they are in tight orbits around hot white dwarf stars (as opposed to massive normal stars), where the small size of the white dwarf permits even closer companion orbits and hence similar or even higher irradiation of the companion by the host. In such systems, light from the companion's day- and night-side atmospheres can be detected and studied directly, as the low luminosity of the white dwarf does not overwhelm that of the companion, and the spectrum of each component peaks in different wavelength bands (ultraviolet and infrared). Brown dwarfs irradiated by white dwarfs can thus serve as useful hot Jupiter analogues.

In this talk I will present the discovery of an extremely irradiated low-mass companion to a hot white dwarf. Our analysis indicates a companion mass of $\approx 72-85$ Jupiter masses, making it a likely brown dwarf with a day-side temperature similar to the Sun's surface, $\approx 6,000\,\mathrm{K}$, and a day-to-night temperature difference of $\approx 3,000\,\mathrm{K}$.

Uncovering the population of close white dwarf binaries using eclipses

Jan van Roestel and the ZTF collaboration

University of Amsterdam & California Institute of Technology

The zoo of compact white dwarf binary stars is diverse, with accreting and detached systems, white dwarfs with different types of companions that span a large range of different masses, and also systems with strong magnetic fields. We have been systematically searching the Zwicky Transient Facility data to find eclipsing compact white dwarf binaries. Eclipses are useful both to identify compact white dwarf binaries (it is a well-defined selection method), but also to characterize the binary systems (by modelling the lightcurves). I will present the sample of eclipsing systems discovered with ZTF so far and discuss what we learned from this sample. This includes a period distribution of 800 white dwarf - red dwarfs binaries which does not so any 'period-spike' between 2 and 3 hrs; a sample of 20 white dwarfs with dark companions which has not revealed any new white dwarf planet systems, but does contain 5 CV period bouncers which confirms the predicted period bouncer population does exist, and also several eclipsing AM CVn systems which have been extremely useful to understand the nature of AM CVn donor stars. I will conclude with a short outlook and how we can use current and future photometric survey telescopes to understand white dwarf population by finding even larger samples of eclipsing white dwarf binary systems.

Evolution of accreting white dwarfs from HST and Gaia

Anna Francesca Pala

European Space Agency
European Space Astronomy Centre, Camino Bajo del Castillo s/n, 28692 Villanueva de la Cañada
Madrid, Spain

Accreting white dwarfs are ideal laboratories in which to test our understanding of the evolution of all types of compact binaries, as they are numerous, nearby and relatively bright. In this talk, I will discuss how the synergy between the Hubble Space Telescope and the ESA Gaia space mission allowed us to derive masses, temperatures and accretion rates for a large sample of accreting white dwarfs. Thanks to these results, we have revealed the presence of an anti-correlation between the average accretion rates and the white dwarf masses, which suggests the presence of an additional mechanism of angular momentum loss not accounted for by most evolutionary models. These results provide new stringent constraints on the models describing the evolution of these binaries and I will present them in comparison with the currently available theoretical framework.

Eclipse Timing of AM CVn Binary Stars

Matthew J. Green, Thomas R. Marsh, Jan van Roestel, Elmé Breedt

Tel Aviv University, Israel; University of Warwick, UK;
University of Amsterdam, the Netherlands; University of Cambridge, UK

An AM CVn-type binary system consists of a white dwarf accreting hydrogen-depleted material from a low-mass, degenerate or semi-degenerate donor star. The secular orbital period evolution of AM CVn binaries is driven by gravitational wave radiation, and they are expected to be among the brightest Galactic sources detectable to space-based graviational wave detectors. The period evolution is predicted to be detectable on a timescale of years. Two eclipsing AM CVn-type binaries, YZ LMi and Gaia14aae, have been observed frequently since 2006 and 2015, respectively. I will present a search for an orbital period derivative among the observed eclipses, and show that for YZ LMi the non-detection of the predicted period derivative is significant at the three sigma level. I will discuss potential reasons for this discrepency.

Over 20 years of the shortest-period binary star system HM Cancri: orbital decay and MESA evolution – AM CVn

James Munday,[1] T. R. Marsh,[1] Ingrid Pelisoli,[1] Danny Steeghs,[1] Mark Hollands,[2] Pasi Hakala,[3] the HiPERCAM team [1,2,4,5,6]

[1]*Department of Physics, Gibbet Hill Road, University of Warwick, Coventry CV4 7AL, United Kingdom*
[2]*Department of Physics and Astronomy, University of Sheffield, Sheffield, S3 7RH, UK*
[3]*Finnish Centre for Astronomy with ESO (FINCA), Quantum, University of Turku, FI-20014, Turku, Finland*
[4]*Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA, UK*
[5]*Instituto de Astrofísica de Canarias, E-38205 La Laguna, Spain*
[6]*Tel Aviv, 69978, Israel*

HM Cancri (HM Cnc) is the shortest-period binary star system, with an orbital period of 321s (frequency of 3.11mHz) and the system is accreting in a double WD configuration. Since its discovery over 20 years ago, we have obtained time-series optical photometry to precisely quantify its orbital decay. We find a positive frequency derivative such that the system is inspiraling, however, the frequency derivative itself is decreasing with time. This is the reverse behaviour to purely gravitational-wave driven evolution and is very likely a consequence of mass accretion. We use the observed orbital decay to investigate system evolutionary models, imposing constraints on system masses and thus the future of the binary. Its ultra-compact nature makes HM Cnc a unique system to test double WD binary star system evolutionary channels and HM Cnc will be one of the first sources detected by the gravitational wave spacecraft LISA, serving as an impactful "verification binary" for instrument calibration.

Angular Momentum Loss in accreting WD binaries

S.P Littlefair, J.F. Wild, Pinsonneault, M., Joyce, Meridith, V.S Dhillon, T.R Marsh, S.G. Parsons

An ongoing problem in the evolution of close white-dwarf binaries is the amount of angular momentum loss (AML) from the binary. Gravitational radiation sets a hard floor on the AML, but the contribution of magnetic wind braking from the main-sequence companion and AML that arises as a consequence of mass transfer is highly uncertain.

The nature of AML in interacting white dwarf binaries drives the location of the period gap and period minimum, but magnetic braking models tuned to isolated stars in open clusters provide orders of magnitude less AML than required to explain these phenomena. Recently, AML arising as consequence of mass transfer has been suggested as an explanation for many current discrepancies between evolutionary theory and observations.

Here I present the preliminary results from a campaign to measure the secular AML rates in interacting white dwarf binaries, using the donor star radius as a measure of the mass-loss rate. I show MESA modelling aimed at recreating the observed donor radii, and discuss the implications of the inferred AML rates.

A ZTF survey for evolved cataclysmic variables turning into extremely low-mass white dwarfs

Kareem El-Badry

Center for Astrophysics — Harvard & Smithsonian, 60 Garden Street, Cambridge, MA 02138, USA

I will describe a systematic survey for mass-transferring and recently-detached cataclysmic variables (CVs) with evolved secondaries, which are progenitors of extremely low mass white dwarfs (ELM WDs), AM CVn systems, and detached ultracompact binaries. We select targets below the main sequence in the *Gaia* color-magnitude diagram with ZTF light curves showing large-amplitude ellipsoidal variability and orbital period $P_{\rm orb} < 6\,{\rm hr}$. We have obtained many-epoch spectra for 21 objects selected this way, about half of the population with $G < 18$. We confirm all of them be completely– or nearly–Roche lobe filling close binaries. About half show evidence of ongoing mass transfer, which has just ceased in the other half. Most of the secondaries are hotter than *any* previously known CV donors, with temperatures $4700 < T_{\rm eff}/{\rm K} < 8000$. Remarkably, all secondaries with $T_{\rm eff}{\gtrsim}7000\,{\rm K}$ appear to be detached, while all cooler secondaries are still mass-transferring. This transition likely marks the temperature where magnetic braking becomes inefficient due to loss of the donor's convective envelope. Most of the proto-WD secondaries have masses near $0.15\,M_{\odot}$; their companions have masses near $0.8\,M_{\odot}$. We infer a space density roughly 80 times lower than that of normal CVs and three times lower than that of ELM WDs. The implied Galactic birth rate is half that of AM CVn binaries. Most systems are well-described by MESA models for CVs in which mass transfer begins only as the donor leaves the main sequence. All are predicted to reach minimum periods $5{\lesssim}P_{\rm orb}/{\lesssim}{\rm min}30$ within a Hubble time, where they will become AM CVn binaries or merge. This sample triples the known evolved CV population and offers broad opportunities for improving understanding of the compact binary population.

X-ray orbital modulation of a candidate period bounce cataclysmic variable

Daniela Muñoz Giraldo[1], Beate Stelzer[1,2]

[1] *Institut für Astronomie and Astrophysik, Eberhard Karls Universität Tübingen, Sand 1, 72076 Tübingen, Germany* [2] *INAF Osservatorio Astronomico di Palermo, Piazza del Parlamento 1, 90134 Palermo, Italy*

Period bounce cataclysmic variables (CVs) are systems where a white dwarf accretes from a brown dwarf donor, having reached a point where the degeneracy of the donor reverses the orbit period evolution. Period bounce CVs are expected by evolutionary models to make up a great portion of the CV population. However, only a few such systems have been identified observationally. We emphasize the importance of X-ray data in order to identify period bounce CVs, as it provides proof of accretion from the substellar companion onto the white dwarf, because in this type of system the coronal emission of the donor is below the sensitivity of current instruments.

We have observed the period bouncer candidate SDSS J151415.65+074446.4 with XMM-Newton and we report here the detection of X-ray orbital modulation. We calculate the orbital period through the analysis of the X-ray lightcurve and we derive a mass accretion rate from the X-ray luminosity. Our analysis establishes SDSS J151415.65+074446.4 as a sibling of SDSS J121209.31+013627.7, the only other white dwarf and L dwarf system confirmed as a period bouncer through its X-ray properties. We provide an outlook of the eROSITA all-sky survey capabilities for the X-ray detection of such systems.

Hard X-ray luminosity function of Cataclysmic Variables in Gaia era

V. F. Suleimanov, V.A. Doroshenko, and K. Werner

Institut für Astronomie und Astrophysik, Kepler Center for Astro and Particle Physics, Universität Tübingen, Sand 1, D-72076 Tübingen, Germany

Cataclysmic variables (CVs) are the most numerous sources of hard X-ray radiation in the Milky Way and believed to be responsible for unresolved hard X-ray emission of the Galactic ridge and the central Galactic regions. Quantitative verification of this hypothesis requires, however, robust observational constraints for the observed hard X-ray luminosity function for CVs. Here we report the most stringent constraints of such kind using X-ray information for all CVs detected in the 105-month BAT Catalogue and distance information for a sub-sample of 79 sources based on Gaia EDR3 parallaxes. We derive that the local number density of hard X-ray emitting CVs per solar mass is $1.37^{+0.3}_{-0.16} \times 10^{-5}$ and the corresponding luminosity density per solar mass is $8.95^{+0.15}_{-0.1} \times 10^{26}\,\mathrm{erg\,s^{-1}}\,M_{\odot}$. The integrated Galactic ridge X-ray emission and nuclear stellar cluster luminosities computed using these values coincide with the observed values in good accuracy. Furthermore, analysis of the differential luminosity functions demonstrates that there are two populations of hard X-ray-emitting CVs. Intermediate polars dominate at luminosities $L > 10^{33}\,\mathrm{erg\,s^{-1}}$, whereas non-magnetic CVs and polars are significant at lower luminosities. Considering the higher abundance of low luminosity systems we find, however, that total contribution of the intermediate polars and other CV types to the observed hard X-ray luminosity is almost equal.

On the determination of fundamental parameters of accreting white dwarfs

Vitaly Neustroev, Jussi Hedemäki

Space Physics and Astronomy research unit, PO Box 3000, FIN-90014 University of Oulu, Finland

Cataclysmic variable stars (CVs) are semidetached binary systems consisting of an accreting white dwarf and a low-mass donor transferring matter to the compact object via the inner Lagrangian point. The knowledge of physical parameters of accreting white dwarfs, such as effective temperature $T_{\rm eff}$ and surface gravity g, is crucially important for the further development of the theory of CV evolution. In particular, the temperature of the white dwarf allows for estimating the mass accretion rate which is a function of system age, while the surface gravity, a function of the mass, is needed to evaluate other system parameters of the binary. The traditional methodology of the parameter determination of *isolated* white dwarfs is fitting the model spectra to observed absorption lines. Spectra of CVs with relatively low mass-transfer rate also often exhibit the clear presence of broad Balmer absorption lines, suggesting using the same approach for measuring the parameters of the white dwarf. However, optical spectra of the *accreting* white dwarfs are contaminated by an accretion disc, the contribution of which is unknown. For this reason, there is a common opinion that optical spectra of the accreting white dwarfs do not allow for accurate constraining $T_{\rm eff}$ and $\log g$ and that instead ultraviolet spectroscopy is necessary. Indeed, the contamination from the accretion disc at these wavelengths is much smaller compared to its contribution at optical wavelengths and therefore can be neglected. Unfortunately, most of the accreting white dwarfs with a low mass-transfer rate are quite dim and only a few of them were observed with Hubble Space Telescope while optical spectra of many such objects were already obtained with large ground-based telescopes.

Here we show that by adopting a simple model for the disc contribution it is possible to constrain $T_{\rm eff}$ and $\log g$ of the accreting white dwarf using optical spectroscopy. We performed extensive testing of our technique by simulating various spectra which consist of synthetic spectra of white dwarfs covering a range of $\log g/T_{\rm eff}$ plus a power-law with the differing contributions of the latter and adding random noise of different levels. We have found that even for a relatively large disc contribution (200%), and a relatively low signal-to-noise ratio SNR$\sim$30, uncertainty estimates of parameters were within our model grid. ($\Delta T_{\rm eff} = 250$ K and $\Delta \log g = 0.25$). We then fitted the spectra of several CVs for which both optical and UV spectroscopy is available. We found a good agreement in the measured parameters of the accreting white dwarfs using our method with those obtained by Pala et al. (2022) from the analysis of UV spectra.

Following our procedure, we have studied more than 15 accreting white dwarfs, including post-period-minimum candidates. We found that the white dwarfs in most of them have a temperature in the range of 10000–15000 K.

Unveiling the nature of two intermediate polars: V902 Mon and SWIFT J0746.3−1608

Nikita Rawat, [1,2] J. C. Pandey, [1] Arti Joshi, [3] Umesh Yadava [2]

[1] *Aryabhatta Research Institute of Observational sciencES (ARIES), Nainital 263001, India*
[2] *Deen Dayal Upadhyaya Gorakhpur University, Gorakhpur 273009, India*
[3] *Indian Institute of Astrophysics (IIA), Koramangala, Bangalore 560034, India*

We have carried out detailed time-resolved timing analyses of two long-period intermediate polars (IPs), namely V902 Mon and SWIFT J0746.3-1608, using the long-baseline, high-cadence optical photometric data from the Transiting Exoplanet Survey Satellite (TESS). We refine the orbital and spin periods of V902 Mon and SWIFT J0746.3-1608 as 8.16 ± 0.03 h and 2207.6 ± 0.5 s, and 9.38 ± 0.04 h and 2249.0 ± 0.6 s, respectively. For both sources, we have found the beat period of 2387.0 ± 0.6 s and 2409.5 ± 0.7 s, respectively, which were not evident in earlier studies. For the eclipsing IP V902 Mon, an apparent orbital period derivative of (6.09 ± 0.60) $\times 10^{-10}$ was also found. Further, the radius of the eclipsed region is estimated to be $\sim 32\ R_{WD}$, indicating the presence of extended emitting regions. Moreover, the second harmonic of orbital frequency dominates the power spectrum of SWIFT J0746.3-1608, suggestive of ellipsoidal modulation of the secondary star. Our analyses in this study hint toward the change in the accretion mode during the entire observing period for both sources and suggest that V902 Mon and SWIFT J0746.3-1608 are most likely to be variable disc-overflow accreting IPs.

A study of TCP J2104, a highly evolved Cataclysmic Variable

Sergio H. Ramirez

The University of Warwick

Despite its proximity (109.2±1.5 pc), the cataclysmic variable TCP J21040470+463112 remained unnoticed until the system went into outburst in 2019. Here we make the first direct study of the white dwarf primary of the highly evolved CV, by analysing far-ultraviolet COS observations obtained with HST. Using the spectrophotometric capabilities of the COS instrument, we integrated the flux of the spectra finding a highly variable lightcurve. We also performed a cross correlation analysis to measure the radial velocity variation of the white dwarf, which we found to be modulated on a period of $\simeq 77\,\mathrm{min}$, consistent with the orbital period found in previous studies. Phase-folding by this period, an orbital fit was made to find the radial velocity of the white dwarf, resulting in a very low radial velocity amplitude – suggestive of a very low-mass donor. Furthermore, the spectra also show two Nitrogen emission lines, whose low velocity, obtained by Gaussian fitting, hints at their origin arising either from the atmosphere of the white dwarf or a close region around it. Finally, we determine the white dwarf effective temperature, surface gravity, and photospheric abundances from the COS spectroscopy. We discuss in detail our results and their physical implications.

Searching for AR Sco 2.0: are other white dwarf pulsars out there?

Ingrid Pelisoli

University of Warwick

The evolution of accreting white dwarfs is driven by competing mechanisms transferring angular momentum between the binary system's orbit and the white dwarf's rotation. These systems can constrain the physics of binary interactions, which is of crucial importance for understanding phenomena such as thermonuclear supernovae and gravitational wave emission by compact binaries. Of particular interest are accreting magnetic white dwarfs, in which the spin period is revealed through photometric variations induced by spots. The origin of these systems is not fully understood — how can these white dwarfs have strong magnetic fields and, at the same time, have accreted enough material to often achieve high spin rates? One of the most remarkable examples identified to date is AR Sco. AR Sco is composed of a low-mass red dwarf star and a rapidly spinning, magnetised white dwarf on a 3.56-hour orbit. It shows strongly pulsed emission over a broad range of wavelengths, from radio to X-rays, with a period of 1.97 minutes, which lead to it being known as a "white dwarf pulsar". Despite its plethora of fascinating properties, AR Sco has remained the only system of its kind even six years after its discovery, preventing us from testing predictions of proposed models. We have performed a systematic search for AR Sco-like objects, relying on *Gaia* astrometry and photometry, and on variability in photometric surveys such as TESS and WISE, to identify objects sharing properties with AR Sco. In this talk, we report the results of this search, including the discovery of a new white dwarf pulsar.

Post-outburst Spectroscopic Investigation of Northern Novae

R. Poggiani[1]

[1] *Dipartimento di Fisica, Università di Pisa, Italy*

The understanding of the nova explosion mechanisms requires systematic investigations of the different stages of evolution with high time cadence. While photometric investigations are routinely performed, spectroscopic observations are generally clustered around the maximum and in the first weeks/months after the outburst. The extensive Tololo and SMARTS spectroscopic atlases of novae are mainly focused on Southern novae. I will present the results of the optical spectroscopic investigation of a sample of Northern novae, covering the stages from the pre-maximum stage, when present, to the nebular stage. The observation have been performed at the Loiano Observatory, Italy. I will present the results about some peculiar novae showing cusps, flares, long pre-maximum stages, gamma ray emission, during their evolution, correlating the optical observations with multi-frequency investigations.

The C/N ratio from FUV spectroscopy as a constraint upon the past evolution of HS0218+3229

Odette Toloza[1]

1.*Departamento de Fisica, Universidad Tecnica Federico Santa Maria, Avenida Espana 1680, Valparaiso, Chile*

No abstract submitted.

3 Abstracts: Posters

The poster numbers are given on the pages (*top*, *right*).

Future space missions for studies of white dwarfs

M.A. Barstow[1] & S.L. Casewell[1]

1. School of Physics & Astronomy, University of Leicester, UK.

Since the last European White Dwarf Workshop in 2018, the space mission landscape has changed considerably. ESA has carried out its Voyage 2050 planning exercise for future missions and the US National Academy of Sciences Decadal survey has published its report. The key output for space astronomy is the recommendation to develop and fly a large, 6-m class, UVOIR observatory. It is highly likely that ESA will take a major role in this NASA-led effort. In addition, ESA issued a call for new M- and F-class missions. The submissions are currently being evaluated. A number of space missions will emerge from these processes that are likely to be of interest for the study of white dwarfs. This paper surveys the missions currently under discussion, evaluates their relevance to studies of white dwarfs and provides guidance for community participation.

A Volume-Complete Sample of Hot Subluminous Objects with Gaia

H.Dawson[1], S.Geier[1], U.Heber[2], I.Pelisoli[3] et al.

[1]*Institute for Physics and Astronomy, University of Potsdam, Karl-Liebknecht-Str. 24/25, 14476 Potsdam, Germany*
[2]*Dr. Remeis-Sternwarte & ECAP, Astronomical Institute, University of Erlangen-Nürnberg, Sternwartstr. 7, D-96049 Bamberg, Germany*
[3]*Department of Physics, University of Warwick, Gibet Hill Road, Coventry CV4 7AL, UK*

Hot subluminous pre-white dwarf objects occupy the sparsely populated region between the main sequence and the white dwarf (WD) cooling track in the Hertzsprung-Russel diagram. A diverse zoo of evolutionary phases can be found here ranging from the transient helium-core WD progenitors and post-AGBs, to the more stable cataclysmic variables (CVs) and helium-burning hot subdwarfs. However, we cannot yet satisfactorily explain the genesis of some members of this group, which remains a missing piece of the puzzle. The ambition of this work is to construct the first spectroscopically confirmed volume-limited sample of these stars within 500 pc using Gaia EDR3. In this poster presentation, I will report on the current status of this sample and aim to deliver a prognosis of its application to a variety of astrophysical fields.

The influence of metals in the luminosity function of white dwarfs

Jordi Isern

Institute of Space Sciences (ICE,CSIC)
Institute for Space Studies of Catalonia (IEEC)
Fabra Observatory, 1st Section, Royal Academy of Sciences and Arts of Barcelona (RACAB)

White dwarfs are almost completely degenerate stars which evolution is driven by the gravo-thermal readjustment of their structure in which the migration of heavier chemical species towards the interior plays an important role. Metals have also some influence on the lifetime and mass of the progenitors of white dwarfs. The problem is that, as a consequence of the short lifetime of metals in their atmosphere, the metallicity of field white dwarfs is not known. One way to avoid this problem is to work with the luminosity function of white dwarfs in wide, non-interacting binaries where the chemical composition of the non-degenerate companion is known.

Towards a volume-limited all-sky sample of extremely low-mass white dwarfs

Ingrid Pelisoli

University of Warwick

Single stellar evolution cannot explain all observed stellar populations. That is not surprising: most stars with one solar mass or above are part of a binary system, and around a quarter of those will interact during their lifetime, giving rise to astrophysical phenomena not witnessed by single stars. One particularly interesting scenario occurs when interaction happens as a star is leaving the main sequence before the onset of core helium burning. This can lead to enhanced mass-loss that allows the formation of so-called extremely low-mass white dwarf stars (ELMs). As remnants of binary evolution, ELMs can shed light onto the poorly understood yet crucial phase of common-envelope evolution and provide constraints to the physics of mass accretion. Most known ELMs were discovered in a magnitude-limited survey of the northern hemisphere using a colour selection, which excluded the cooler end of the population. In order to fully test theoretical models and their predictions, a sample covering all predicted ELM properties is required. This poster presents efforts towards obtaining a volume-limited sample all-sky sample of ELMs to serve as a benchmark for theoretical models.

Kinematics and population membership of white dwarfs from the MMT survey

S. Weich (1), S. Kreuzer (1), U. Heber (1), M. Dorsch(1), A. Irrgang(1), R. Raddi(2), D. Koester(3)

1) Dr. Karl Remeis-Observatory and ECAP, Astronomical Institute, Friedrich-Alexander University Erlangen-Nuremberg (FAU), Sternwartstr. 7, 96049 Bamberg, Germany
2) Universitat Politcnica de Catalunya, Departament de Fsica, c/ Esteve Terrades 5, 08860 Castelldefels, Spain
3) Institut für Theoretische Physik und Astrophysik, Christian-Albrechts-Universität, Kiel 24118, Germany

A spectroscopic survey for blue horizontal branch stars and blue stragglers was carried out at the MMT observatory (Brown et al. 2010a). Spin-offs of this survey were the discovery of enigmatic objects such as hyper-velocity stars and extremely low mass (ELM) white dwarfs, which led to the launch of daughter surveys dedicated to search for such objects (Brown et al. 2006, 2010b).

In the full MMT sample of about 1800 objects 401 DA white dwarfs with surface gravities log (g) >7.0 have recently been identified and quantitative spectroscopic analyses were carried out (see Heber et al, this conference). The unprecedented precision of *Gaia* EDR3 astrometry allows us to verify spectroscopic distances. Morever, a kinematic analysis using *Gaia* proper motions and measured radial velocities makes it feasible to derive the kinematical properties of the sample and to assign individual stars to stellar populations.

References:

Brown et al. 2006, ApJ, 647, 303
Brown et al. 2010a, AJ, 139...59B
Brown et al. 2010b, ApJ, 723, 1072

Analysis of a polluted DAZ white dwarf with high metal abundances

Anna-Maria Cutolo

Department of Physics, University of Warwick, Coventry, CV4 7AL, UK

As main sequence stars evolve into white dwarfs, we expect the outer planets and other bodies in the system to survive evaporation by or engulfment into the giant branch star. White dwarf atmospheres are primarily H/He, and so the detection of metals in their spectra is a sign of pollution from the accretion of planetary material. By analysing the photospheric abundances and comparing them to Solar System benchmarks – for example, bulk Earth, mantle or crust compositions, or individual asteroid families – we are able to determine the composition of extra-solar planetary bodies, which in turn provides crucially important information on the formation and evolution of planets.

We present the analysis of WD J0358+2157, a cool and strongly polluted DAZ white dwarf with strong lines of Mg, Al, Si, Ca, Ti, and V. We fitted Koester atmosphere models [1] to the X-Shooter spectra and photometric data of the star using MCMC methods to determine $T_{\rm eff}$, $\log g$ and detailed metal abundances. So far we have estimated these to be $T_{\rm eff} \simeq 6500\,$K, $\log g \simeq 8.15$, and overall metal abundance $[\mathrm{Ca/H}] \simeq -7.6$. We conclude that WD J0358+2157 is the most heavily polluted cool DAZ, currently accreting planetary debris at a high rate – as such, it is the first equivalent to the large sample of strongly polluted cool helium atmosphere white dwarfs (e.g. [2]) which have very long ($\simeq 10^6\,$yr) diffusion timescales compared to hydrogen atmospheres, and so have most likely finished the accretion episode.

References

[1] Koester, D. White dwarf spectra and atmosphere models, *Memorie della Societa Astronomica Italiana*, vol. 81, pp. 921931, 2010.

[2] Hollands, M. et al., Cool dz white dwarfsi. identification and spectral analysis, *Monthly Notices of the Royal Astronomical Society*, vol. 467, no. 4, pp. 49705000, 2017.

Kinematics of massive white dwarfs with(out) metal pollution to constrain planetary occurrence rates in intermediate-mass stars

Lou Baya Ould Rouis[1], JJ Hermes[1]

[1]*Institute for Astrophysical Research, Boston University, Boston, MA 02215, USA*

Massive white dwarfs (0.8-1.3 $M_\odot$) may provide the best way to constrain planetary occurrence around intermediate mass main sequence stars (4-7 $M_\odot$). We want to assess whether these occurrence rates represent single star evolution alone or if there is stellar merger contamination. We use objects with UV spectra from the HST Snapshot program that is sensitive to white dwarf metal pollution to quantify merger contamination. High precision astrometric surveys have allowed us to get the velocity distributions of hundreds of thousands of white dwarfs in our galaxy. We use these distributions to compare observed kinematics with those derived from total ages. Since massive white dwarfs are expected to be slow, we can attempt to quantify merger byproducts by identifying the portion of high velocity massive white dwarfs.

Magnetic White Dwarfs Recreated in HEDP Laboratory Settings

Z.S. Berbel, D.E. Winget, M.H. Montgomery

University of Texas at Austin

Fitting spectral lines of white dwarfs (WD) to model atmospheres is the most common way to determine fundamental properties of temperature and surface gravity. However, this becomes more difficult in the presence of magnetic fields, which split and can even shift the lines with increasing field strength. About one-fourth of all WDs are impacted by this Zeeman effect, hosting magnetic fields that range from kilogauss up to gigagauss strengths. Magnetic WDs also have statistically higher masses than their non-magnetic counterparts, giving additional importance to understanding how WD atmosphere conditions behave in magnetic fields. The altered spectral lines are treated with the robust theory developed for all different field strength regimes of the Zeeman effect. However, all good theory should be backed by experimentation. As of 2022, there have been no dedicated experiments to recreate the Zeeman effect in WD conditions in a laboratory setting, but there have been magnetized HEDP experiments that fall within these conditions nonetheless. Here, I present a look into where magnetized HEDP experiments have probed the parameter space of magnetic WDs, with a focus on the spectroscopic determination of magnetic fields in the relevant WD conditions.

A Spectro-photometric Analysis of Cool White Dwarfs in the Gaia and Pan-STARSS Footprint

Alexandre Caron[1], Pierre Bergeron[1], Sandy K. Leggett[2], and Simon Blouin[3]

[1]*Dpartement de Physique, Universit de Montral, C.P. 6128, Succ. Centre-Ville, Montral, QC H3C 3J7, Canada*

[2]*Gemini Observatory, 670 N. Aohoku Place, Hilo, HI 96720, USA*

[3]Department of Physics and Astronomy, University of Victoria, Victoria, BC V8W 2Y2, Canada

We present a spectro-photometric analysis of 2850 cool white dwarfs below $T_{\rm eff} \sim 10,000$ K and within 100 pc, with *grizy* Pan-STARRS photometry and Gaia trigonometric parallaxes available. We also supplement our data sets with near-infrared JHK photometry, when available, which is shown to be essential for interpreting the coolest white dwarfs in our sample. We perform a detailed analysis of each individual object using state-of-the-art model atmosphere grids appropriate for each spectral type including DA, DC, DQ, DZ, He-rich DA, and the so-called IR-faint white dwarfs. We discuss the temperature and mass distributions of each subsample, as well as revisit the spectral evolution of cool white dwarfs. We also offer an explanation for the low masses often reported at the end of the white dwarf cooling sequence.

The class of magnetic Helium-sdOs: progenitors to strongly magnetic DA(O)s

Matti Dorsch[1,2], Ingrid Pelisoli[3], Stephan Geier[2], Ulrich Heber[1], Nicole Reindl[2], Boris Gauml;nsicke[3], et al.

[1] *Remeis-Observatory Bamberg, FAU Erlangen-Nuuml;rnberg* [2] *Universitauml;t Potsdam* [3] *University of Warwick*

Magnetic fields play an important role throughout stellar evolution, and among white dwarfs, the end stage of 95% of all stars, the fraction of strongly magnetic systems is larger than about 20%. The origins of magnetic white dwarfs are still under discussion, but it is likely that a significant fraction of them are formed by stellar mergers.

Several types of merger remnants are thought to ignite helium fusion, such as the merger of a helium-WD with a second He-WD, a He/C/O hybrid WD, or a low-mass main sequence star, thus forming a hot subdwarf star. In particular, most of the hot and helium-rich He-sdO stars are thought to be formed by mergers. However, out of hundreds of hot subdwarfs studied over several decades, none showed detectable magnetic fields. This changed recently, when four almost identical magnetic He-sdO stars were discovered, with mean field strengths between 300 and 500kG. Why are these stars magnetic while vast majority of other He-sdOs are non-magnetic? This question is still open. What is fairly certain is that the four magnetic He-sdOs will evolve to become strongly magnetic DA(O) WDs.

DESI establishes DAQ white dwarfs as a distinct spectral class consistent with a white dwarf merger origin.

Boris T. Gänsicke[1], Christopher J. Manser[1,2], Detlev Koester[3]

[1] *Department of Physics, University of Warwick, Coventry CV4 7AL, UK*
[2] *Astrophysics Group, Department of Physics, Imperial College London, Prince Consort Rd, London, SW7 2AZ, UK*
[3] *Institut für Theoretische Physik und Astrophysik, University of Kiel, 24098 Kiel, Germany*

The *Gaia* astrometry has been revolutionary for white dwarf science, identifying several 100,000 white dwarf candidates. A structure early recognised in the *Gaia* Hertzsprung-Russell diagram is a distinct branch of very massive white dwarfs, and their nature and origin is still under discussion. A possible merger origin for (at least some of them) is supported by the discovery of a massive DAQ white dwarf with an extremely thin H/He envelope (Hollands et al. 2020). We present the analysis of 17 DAQ identified by the DESI survey, and demonstrate that all of them are massive white dwarfs clustering on the "Q-branch" – consistent with being remnants of double-degenerate mergers. The one exception is a DA+DQ double-degenerate, which, as expected, is located in the HRD above the white dwarf cooling track. We conclude that there is growing evidence that the "Q-branch" is the result of white dwarf mergers, though, the diverse spectroscopic appearance along this sequence is still puzzling.

White dwarfs from the MMT survey

U. Heber (1), S. Kreuzer (1), S. Weich (1), M. Dorsch(1), A. Irrgang(1), R. Raddi(2), D. Koester(3)

1) Dr. Karl Remeis-Observatory and ECAP, Astronomical Institute, Friedrich-Alexander University Erlangen-Nuremberg (FAU), Sternwartstr. 7, 96049 Bamberg, Germany
2) Universitat Politcnica de Catalunya, Departament de Fsica, c/ Esteve Terrades 5, 08860 Castelldefels, Spain
3) Institut fr Theoretische Physik und Astrophysik, Christian-Albrechts-Universitt, Kiel 24118, Germany

A spectroscopic survey for blue horizontal branch stars and blue stragglers was carried out at the MMT observatory (Brown et al. 2010a). This survey led to the discovery of enigmatic objects such as hyper-velocity stars and extremely low mass (ELM) white dwarfs, which triggered the launch of daughter surveys dedicated to search for such objects (Brown et al. 2006, 2010b). Kilic et al. (2007) revisited 42 ELM WD candidates and found 40 of them to be normal DA white dwarfs, probably because SDSS photometry was inaccurate. We investigate the spectra of the full sample of $\approx$ 1800 MMT candidates and found 401 objects to be normal DA white dwarfs with surface gravities log (g) >7.0. A cross-match of our WD sample with other WD catalogues showed that a large number has not been studied before, some not even been identified as candidates. This work, hence, provides accurate atmospheric parameters for 339 candidates from the catalog of Gentile Fusillo et al. (2021) as well as of previously unknown WDs.

The sample is well defined in colour-magnitude space. This was sufficient motivation for us to carry out quantitative spectral analyses to determine atmospheric parameters. Fundamental stellar parameters (mass, radius and luminosities) of the WDs were also derived by making use of spectral energy distributions and evolutionary models.

References:

Brown et al. 2006, ApJ, 647, 303
Brown et al. 2010a, AJ, 139...59B
Brown et al. 2010b, ApJ, 723, 1072
Kilic et al. 2007, ApJ, 660, 1451

Incorporating Xenomorph Hydrogen Line Shapes into White Dwarf Model Spectra

Bryce Hobbs[1], Thomas Gomez[1,2], Zethran Berbel[1], Michael Montgomery[1], Don Winget[1]

[1]*Department of Astronomy, The University of Texas at Austin, Austin, TX 78712, USA*
[2]*Sandia National Laboratories, Albuquerque, NM 87123, USA*

Accurate spectral Line shapes are needed in order to determine log g and T_{eff} of white dwarfs. This work aims to quantify the change in derived spectroscopic temperature and surface gravity of DA white dwarfs when substituting standard Hydrogen α, β, and γ line profiles in the synthetic spectra with new Xenomorph profiles (Cho et al. 2022). Future work will examine how these new model atmospheres revise the discrepancy between spectroscopic and photometric parameter estimations.

Hot White Dwarfs from the SALT Survey of Helium-Rich Hot Subdwarfs

Simon Jeffery[1], K. Werner[2], B. Miszalski[3,5], I. Monageng[4], 5, E.J. Snowdon[1], L.J.A. Scott[1], V.M. Woolf [6]

1. Armagh Observatory and Planetarium. 2. Universität Tübingen 3. Australian Astronomical Optics. 4. University College Cape Town. 5. South African Astronomical Observatory. 6. University of Nebraska at Omaha.

A spectroscopic survey of helium-rich hot subdwarfs is being carried out with the Southern African Large telescope (SALT). The first data release provided methods, classification and analyses for ∼100 stars. Some 300 stars have now been observed and classified. Survey selection was based on stars classified as He-sdB, He-sdOB and He-sdO or their equivalents in various catalogues of hot subdwarfs. These low-resolution classifications have broad error margins; consequently the sample includes a number of stars which turn out to be white dwarfs, including classical DB white dwarfs through to very hot DO and DAO white dwarfs, some of which are new to science. We report on these observations.

The Python White Dwarf Photometric SED fitter

Marco C. Lam

School of Physics and Astronomy, Tel Aviv University, Tel Aviv, Israel 69978

No abstract submitted.

BD+39 3226: Spectral analysis of ORFEUS II and FUSE observations

Rodrigo Moraga, Thomas Rauch, and Klaus Werner

University of Tübingen, Germany

BD+39 3226 is an O-type subdwarf (sdO) exhibiting an almost pure helium-line spectrum in the optical wavelength range. High-resolution ultraviolet échelle spectra were obtained in 1996 with the Orbiting and Retrievable Far- and Extreme Ultraviolet Spectrometer (ORFEUS II mission) to measure the interstellar deuterium and molecular hydrogen column densities in the line of sight towards the sdO. To model the stellar contribution to the hydrogen Lyman lines, an effective temperature of $T_{\text{eff}} = 45\,000\,\text{K}$, a surface gravity of $\log(g\,/\,\text{cm/s}^2) = 5.5$, and photospheric number fractions of n(He)= 0.99 and n(H)= 0.01 were used, adopted from a previous spectral analysis (Giddings 1980, $T_{\text{eff}} = 44\,700 \pm 5\,000\,\text{K}$, $\log g = 5.5 \pm 0.5$) with H+He composed model atmospheres in non-local thermodynamic equilibrium (NLTE).

Weak and narrow photospheric C III + IV, N III + V, Si III + IV, P V, and S V lines were already identified in the ORFEUS II observation. Subsequent Far Ultraviolet Spectroscopic Explorer (FUSE) spectra from 2004 were used then to investigate D/H and D/O variations (using the same photospheric parameters like before).

A detailed spectral analysis of BD+39 3226 by means of state-of-the-art NLTE model-atmosphere techniques is still outstanding. We employ the Tübingen Model-Atmosphere Package (TMAP) to calculate such models that consider opacities of H, He, C, N, O, Si, P, S, and the iron-group (Ca - Ni) elements. Preliminary results are a higher $T_{\text{eff}} = 49\,000 \pm 2\,000\,\text{K}$ and a significant higher $\log g = 6.2 \pm 0.2$.

We present our still ongoing analysis of the stellar and interstellar spectrum. The latter is performed with the profile-fitting procedure OWENS developed by M. Lemoine and the FUSE French Team.

On the evolution of the hot subdwarf KS 292

Antonia Queitsch, Thomas Rauch, and Klaus Werner

University of Tübingen, Germany

KS 292 is an subluminous O-type subdwarf star (sdO). A previous spectral analysis determined its stellar parameters (Rauch et al. 1991, $T_{\rm eff} = 75\,000$ K, $\log(g/\text{cm/s}^2) = 5.0$) using non-local thermodynamic equilibrium (NLTE) model-atmosphere calculations that considered H, He, C, and N. This analysis was based on observations from the ESO Cassegrain Echelle Spectrograph (CASPEC) und the International Ultraviolet Explorer (IUE). The evolutionary state of KS 292 could not be unambiguously explained, it may either be a post-EHB or a post-AGB star.

Since then, new high-resolution spectra in the far-ultraviolet wavelength area from the Orbiting Far- and Extreme Ultraviolet Explorer (ORFEUS) and from the Far Ultraviolet Spectroscopic Explorer (FUSE) were obtained and analysed in this work. Also, advanced models were calculated with Tübingen NLTE Model-Atmosphere Package TMAP), and additionally, the elements O, F, Al, Si, P, S, and the iron group (Ca-Ni) were considered. The first results are a significant lower $T_{\rm eff} = 65\,000$ K (determined by the evaluation of ionization equilibria, e.g., N III/IV/V) and a slightly higher log g= 5.1.

We present preliminary results of our spectral analysis and discuss the evolution of KS 292.

Continuum linear polarization of white dwarfs in R band - summary of the RoboPol survey

Agnieszka Slowikowska (1), Dmitry Blinov (2,3), Pablo Reig (3,2)

(1) Institute of Astronomy, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University in Torun, Grudziadzka 5, PL-87-100 Torun, Poland; (2) Institute of Astrophysics, Foundation for Research and Technology-Hellas, Voutes, 71110 Heraklion, Greece; (3) Department of Physics, University of Crete, 71003, Heraklion, Greece

In my talk, I will summarise the results of the linear polarization survey of white dwarfs (WDs) in the R band with the RoboPol polarimeter. We observed more than 130 WDs isolated and in the binary systems. We found that the median polarization degree of isolated DA WDs and DB WDs is similar but lower than the median polarization of isolated DC WDs. The DB WDs in binaries are more polarized than binaries containing DA+dM or double-degenerated systems (DDSs) with DA components. Additionally, we present the linear optical polarisation measurements of both components of some common proper motion binary systems for the first time. Our sample's highest linear polarization degree is measured for the DC isolated WD 0313+393 (GD 44) at 2.18%+/-0.34%. The vast majority of WDs show polarization degree lower than 0.5%. Therefore they can be used as faint low linear polarization standard stars.

Linear and circular polarization of the polluted ZZ Psc

Agnieszka Slowikowska (1), Sloane J. Wiktorowicz (2), Larissa A. Nofi (2), Amanda J. Bayless (2), James R. Graham (3) Maxwell A. Millar-Blanchaer (4), Kimberly Bott (5) and Jon C. Mauerhan (1)

(1) Institute of Astronomy, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University in Torun, Grudziadzka 5, PL-87-100 Torun, Poland; (2) Remote Sensing Department, The Aerospace Corporation, El Segundo, CA 90245; (3) Astronomy Department, University of California, Berkeley, CA 94720; (4) Physics Department, University of California, Santa Barbara, CA 93106; (5) Earth and Planetary Sciences Department, University of California, Riverside, CA 92521

This talk presents the linear and circular polarization results of ZZ Psc (G29-38, WD 2326+049) measurements obtained with the POLISH2 polarimeter at three telescopes; 8-m Gemini North, 3-m Shane and 1-m Lick. ZZ Psc is a nearby, pulsating DA white dwarf with infrared excess caused by the circumstellar dust. POLISH2's photoelastic modulators, employed instead of rotating waveplates or ferroelectric liquid crystal modulators, offer the unprecedented ability to achieve sensitivity and accuracy of order one ppm (0.0001%), which are difficult to obtain via conventional instruments. We detect WD pulsations as well as polarimetric changes correlated with the pulsations. We compare our results with the HIPPI-2 polarimeter measurements presented by Cotton et al. (2020).

New simulations of accreting DA white dwarfs

G. Vauclair (1,2) F.C. Wachlin (3) S. Vauclair (1,2) L.G. Althaus (3)

1 : Université de Toulouse, IRAP, France 2 : CNRS, IRAP, 14 avenue Edouard Belin, 31400, Toulouse, France 3 : Instituto de Astrofisica de La Plata (UNLP-CONICET), Facultad de Ciencias Astronomicas y Geofisicas.Universidad Nacional de La Plata, Argentina

What happens to planetary systems when the central stars reach the late stages of stellar evolution? Debris disks have been discovered around white dwarfs and spectroscopic observations prove that ex-planetary matter is presently falling on the atmospheres of many of these dying stars. Detailed studies of this remaining matter may lead to constraints on the original planetary system, provided that the connection between the presently observed abundances and that of the original falling matter is correctly computed. Many studies have been performed, considering only gravitational settling below the convective zone. Most of them neglect thermohaline convection (also called fingering convection), a hydrodynamical effect that may be important, specially for DA white dwarfs. Considering this effect together with gravitational settling implies accretion rates substantially larger than obtained when ignoring it. We have performed numerical simulations taking these processes properly into account for a range of effective temperatures, hydrogen mass fractions and accretion rates. We discuss the rates we have obtained, and compare them with the one recently derived from X-ray observations of the DAZ G29-38.

Discovery of C/O-rich hot subdwarfs: The WD-merger route to PG1159 stars

Klaus Werner[1], Nicole Reindl[2], Stephan Geier[2], Max Pritzkuleit[2]

[1] *Universität Tübingen, Germany,* [2] *Universität Potsdam, Germany*

We announce the discovery of two hydrogen-deficient sdO stars that exhibit unusually strong carbon and oxygen lines. Our NLTE analysis reveals astonishingly high abundances of C ($\approx$20%, by mass) and O ($\approx$20%) and that the two stars are located close to the helium main sequence. Both objects establish a new spectroscopic class of hot hydrogen-deficient subdwarfs (CO-sdO) and can be identified as the remnants of a helium-core white dwarf that accreted matter of a merging low-mass CO-core white dwarf. We conclude that the CO-sdOs represent an alternative evolutionary channel creating PG1159 stars besides the evolution of single stars that experience a late helium-shell flash.

Pitfalls of Incorporating Quasi-Molecular Features in White Dwarf Model Atmospheres

Jackson White[1], Thomas Gomez[1,2], Bart Dunlap[1], and Michael Montgomery[1]

[1]*Department of Astronomy, The University of Texas at Austin, Austin, TX 78712, USA*
[2]*Sandia National Laboratories, Albuquerque, NM 87123, USA*

Quasi-molecular satellites are a significant source of opacity in white dwarf atmospheres, particularly near Lyman-α. Combining the contribution of quasi-molecular profiles with standard Stark broadened profiles in such a way as to preserve their interaction is challenging, so simplifications are often made which assume the two profiles can be simply added together. However, quasi-molecular broadening and Stark broadening are not independant processes and this assumption may have a significant effect on theoretical line shapes. In this poster we test the validity of different methods for combining separate hydrogenic line shapes broadened by plasma electrons and protons by comparing them to profiles with simultaneous consideration of the plasma particles. We discuss the impact these approximations have on emergent white dwarf spectra and highlight a deficiency in current quasi-molecular calculations.

Spectroscopic and Photometric Observations of Massive White Dwarfs in the μ Tau Stellar Association

Kurtis A. Williams[1], Nicole Reindl[2], Klaus Werner[3], Michael Bolte[4], Isabel Kain[4]

[1] *Department of Physics & Astronomy, Texas A&M Univeristy-Commerce, PO Box 3011, Commerce, TX, 75429, USA*
[2] *Institut für Physik und Astronomie, Universität Potsdam, Haus 28, Karl-Liebknecht-Str. 24/25, 14476, Potsdam-Golm, Germany*
[3] *Institute for Astronomy and Astrophysics, Kepler Center for Astro and Particle Physics, Eberhard Karls University, Sand 1, D-72076 Tübingen, Germany*
[4] *UCO/Lick Observatory, University of California Santa Cruz, Santa Cruz, CA, 95064, USA*

White dwarf members of simple stellar populations such as open star clusters and stellar associations are especially powerful probes of post main sequence and white dwarf evolution, as many properties such as stellar ages and metallicity are known. Gagné et al (2020) announced the discovery of the 60 Myr old μ Tau Association, located only 150 pc away. This association contains two very hot, massive white dwarf - a DA and a WD of uncertain spectral type. We present follow up photometric and high signal-to-noise spectroscopic observations of both white dwarfs. From this we better determine the mass of the DA. We also find that the other WD is rapidly rotating and analyze the phase-resolved spectrum of this peculiar object.

Explaining ZZ Ceti Outbursts by Parametric Instability

Keaton J. Bell

NSF Astronomy & Astrophysics Postdoctoral Fellow
DIRAC Institute, Department of Astronomy, University of Washington

Extensive time series photometry of ZZ Ceti (pulsating hydrogen-atmosphere white dwarf) variables from Kepler/K2 revealed an outburst-like phenomenon that is common near the cool edge of the instability strip. Outbursts cause up to 40% brightness increases, recurring irregularly on timescale of days to months. This unexpected behavior can be explained by a parametric instability model, where driven pulsation modes transfer energy into the convection zone, heating the photosphere and disrupting the pulsations. I present an update on the observational properties of the ensemble of known outbursting ZZ Cetis, and I show how each observable is consistent with the parametric instability model. This talk aims to provide satisfying closure to the mystery of outbursting pulsating white dwarf stars that has been presented and discussed at recent EuroWD Workshops.

Asteroseismic study of KUV03442+0719 with parallax constraints

Agnès Bischoff-Kim

Penn State Scranton, Dunmore, Pennsylvania, USA

We perform the asteroseismic analysis of the pulsating hydrogen atmosphere white dwarf, KUV03442+0719. In addition to the unusually rich period spectrum of the star (for this class of objects), we also bring to bear constraints from Gaia parallaxes to find a best fit model. We contrast our result with previous work done on the object. The main disagreement arises in the identification of the radial overtone values for the modes, leading to different conclusions about the parameters and structure of the star. We are able to find a best fit model that is (mostly) consistent with all the data we have for the star (pulsations, spectroscopy, parallax). We also find that the asteroseismology shows a strong preference for models with envelopes that are fully differentiated, consistent with what we expect from stellar evolution models. This work has been submitted to a journal for publication. The aim of this poster is to highlight the main points of that work.

Asteroseismology of White Dwarfs in K2

Barbara G. Castanheira

Baylor University

No abstract submitted.

Asteroseismology of hydrogen-deficient white dwarfs with *TESS*

Alejandro H. Córsico

(1) Grupo de Evolución Estelar y Pulsaciones. Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, Paseo del Bosque s/n, 1900 La Plata, Argentina. (2) IALP - CONICET; La Plata, Argentina

The high-quality photometric data delivered by space telescopes, such as the ongoing *TESS* spacecraft program, is revolutionizing the area of white-dwarf asteroseismology. Among the different kinds of pulsating white dwarfs, there are the ones that have O-, C- and He-rich atmospheres, and they are called pulsating PG1159 or GW Variable stars. Also, there are pulsating white dwarfs with He-rich atmospheres, called DBVs or V777 Her variable stars. Both kinds of pulsating stars are examples of H-deficient variable stars. We present an account of detailed asteroseismological analyses of GW Vir and DBV stars including the observations collected by the *TESS* mission. We processed and analyzed *TESS* observations of GW Vir and DBV stars and performed detailed asteroseismological analyses of these stars on the basis of state-of-the-art PG1159 and DB white-dwarf evolutionary models. We constrained the stellar mass of these stars by comparing the observed period spacing with the average of the computed period spacings, and, when possible, we employed the individual observed periods to search for a representative seismological model. We detected potential frequency multiplets for several target stars, which we use to identify pulsation modes as well as determine rotation periods.

Title: New DA white dwarf models for asteroseismology of ZZ Ceti stars

Leandro G. Althaus & Alejandro H. Córsico

(1) Grupo de Evolución Estelar y Pulsaciones. Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, Paseo del Bosque s/n, 1900 La Plata, Argentina. (2) IALP - CONICET; La Plata, Argentina

White dwarf asteroseismology has a great potential to infer the evolutionary status and chemical stratification of these stars, and to shed light on the physical processes that lead to their formation. We present a new grid of DA white dwarf models that take into account the advances in the last decade in the modeling and input physics of both progenitor and white dwarf stars, thus avoiding several shortcomings present in previous works. These new models are derived from a self-consistent way with the changes in the internal chemical distribution that result from the mixing of all the core chemical components induced by mean molecular weight inversions, from ^{22}Ne diffusion, Coulomb sedimentation, and from residual nuclear burning. In addition, the expected nuclear burning history and mixing events along the progenitor evolution are accounted for, in particular the occurrence of third dredge-up, which determines the properties of the core and envelope of post-AGB and white dwarf stars, as well as the initial-final mass relation. The range of hydrogen (H) envelope thickness of our new ZZ models extends from the maximum residual H content predicted by the progenitor history, to $\log(M_{\rm H}/M_\star) \sim -13$. This opens the possibility, for the first time, of doing asteroseismological studies of ZZ Ceti stars with ultra-thin H envelopes.

Pulsations of relativistic ultra-massive white dwarfs

Alejandro H. Córsico[1,2], Leandro G. Althaus[1,2] & María E. Camisassa[3]

(1) Grupo de Evolución Estelar y Pulsaciones. Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, Paseo del Bosque s/n, 1900 La Plata, Argentina. (2) IALP - CONICET; La Plata, Argentina. (3) Department of Applied Mathematics, University of Colorado, Boulder, CO 80309-0526, USA.

Ultra-massive ($M_\star \geq 1.05 M_\odot$) hydrogen-rich white-dwarf stars of spectral type DA are expected to be partially crystallized by the time they reach the ZZ Ceti (or DAV) instability strip ($10\,500 \leq T_{\rm eff}/{\rm K} \leq 12\,500$ K), stage in which they become pulsating stars. The ultra-massive ZZ Ceti stars known up to date have masses slightly below $\sim 1.3\ M_\odot$, thanks to which it is possible to study their pulsations in the context of Newtonian theory of stellar oscillations. However, it would be possible that more massive pulsating DA white dwarfs could be identified in the coming years with the advent of huge volumes of high-quality photometric data collected by space missions such as the ongoing *TESS* mission and the future *Plato* space telescope. In that case, the importance of General Relativity effects for the structure and pulsations of ultra-massive ZZ Ceti stars cannot be neglected, and it will be necessary to consider pulsational models of relativistic ultra-massive white dwarfs. In this work, we present the first results of the calculation of pulsations in relativistic white dwarfs. As a first step, we consider stellar models of ultra-massive white dwarfs computed within the framework of the general theory of relativity, but compute pulsations in the context of Newtonian theory of stellar oscillations. We describe the differences we find in the typical g-mode periods of ZZ Ceti stars, as compared with the case in which we consider Newtonian models of ultra-massive white dwarfs. In a second step, we will take into account the effects of General Relativity on the non-radial stellar pulsations too.

Discovery of Ultra-Massive DAVs with Implications for Core Crystallization

M. Kao[1], Z. Vanderbosch[2], D. Winget[1], M. Montgomery[1]

[1]*Department of Astronomy, University of Texas at Austin, Austin TX 78701, USA*
[2]*Department of Physics, California Institute of Technology, Pasadena CA 91125, USA*

White dwarf (WD) interiors crystallize below a certain temperature and release latent heat, which causes a delay in the WD cooling process. The temperature of the onset of crystallization scales with mass, so high-mass WDs begin to crystallize at a higher temperature than WDs of lower masses. A majority of WDs are around $0.6M_{\odot}$ and begin crystallization at temperatures below the range where hydrogen-atmosphere (DA) WDs pulsate, so probing the crystalline interiors through asteroseismology is not possible. Using data from *Gaia* and the Zwicky Transient Facility, we have identified about 30 candidate pulsators with masses high enough to be undergoing core crystallization within the pulsational instability strip. Four of these are confirmed pulsators, but the others have little to no photometric or spectroscopic data. This provides us a unique opportunity to study their pulsations through time-series photometry and study the physics of phase separation and chemical redistribution in their cores. Pulsators with suitable properties could allow us to constrain the cooling rate and the crystallized mass fraction of the interior.

White Dwarf Rotation Periods

S. O. Kepler

Instituto de Física, Universidade Federal do Rio Grande do Sul, Brazil

I analysed all the 120 s and 20 s cadence data for the many thousands white dwarfs observed by the TESS satellite, and determined the statistically significant variability period, excluding pulsations, for over 1000 stars. The 1/1000 false-alarm probability limit was calculated by random shuffling the data 1000 times. The dataset is large enough to separate binaries, low mass, high mass and magnetic ones, and study their period distribution.

Multiplet Structure Observed in EC14012-1446

J.L. Provencal & A. Holtz

The University of Delaware And Mt. Cuba Observatory

EC14012-1446 is a pulsating DAV white dwarf observed by the K2 mission as well as by the Whole Earth Telescope. The K2 data set spans 78 days, and the WET data set spans 23 days. We look in detail at the multiplet structure present in both data sets, identify modes involved in structure of interest, and present arguements for oblique rotation.

Asteroseismic analysis of the polluted white dwarf G29−38 with *TESS*

Murat Uzundag[1,2], Francisco De Gernimo[3,4], Alejandro H. Córsico[5], Roberto Silvotti[6], Paul A. Bradley[7], Odette Toloza[8], S. O. Kepler[9], Leandro G. Althaus[5], Mrcio Catelan[3,4]

1. *Instituto de Física y Astronomía, Universidad de Valparaíso, Gran Bretaña 1111, Playa Ancha, Valparaíso 2360102, Chile*
2. *European Southern Observatory, Alonso de Cordova 3107, Santiago, Chile*
3. *Instituto de Astrofísica, Pontificia Universidad Católica de Chile, Av. Vicua Mackenna 4860, 7820436 Macul, Santiago, Chile*
4. *Millennium Institute of Astrophysics, Nuncio Monseñor Sotero Sanz 100, Of. 104, Providencia, Santiago, Chile*
5. *Grupo de Evolución Estelar y Pulsaciones. Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, Paseo del Bosque s/n, 1900 La Plata, Argentina*
6. *INAF-Osservatorio Astrofisico di Torino, strada dell'Osservatorio 20, 10025 Pino Torinese, Italy*
7. *XCP-6, MS F-699 Los Alamos National Laboratory, Los Alamos, NM 87545, USA*
8. *Departamento de Fisica, Universidad Tecnica Federico Santa Maria, Avenida Espana 1680, Valparaiso, Chile*
9. *Instituto de Física, Universidade Federal do Rio Grande do Sul, 91501-970, Porto-Alegre, RS, Brazil*

The DAV G29-38 (TIC422526868) is one of the brightest ($V = 13.1$) and closest ($d = 17.5$ pc) white dwarfs that was observed by the *TESS* spacecraft. The *TESS* data set spans ~ 23 days, and from this we extracted more than 25 significant pulsation frequencies using a standard pre-whitening procedure. All the oscillation frequencies that we found are associated with g(gravity)-mode pulsations, with periods spanning from 240 s to 1200 s. We apply standard seismic tools for mode identification, including asymptotic period spacings and rotational frequency multiplets. Using the g-mode rotational splitting multiplets, we derive a rotation period of about 1.2 days, in agreement with previous determinations. Based on the values obtained from Kolmogorov-Smirnov and Inverse Variance statistical tests, we search for a constant period spacing for dipole ($\ell = 1$) and quadrupole ($\ell = 2$) modes. We find a constant period spacings of 39.47 s for $\ell = 1$ modes and 25.53 s for $\ell = 2$ modes, which allow us to constrain its stellar mass and the harmonic degree of the modes. We identify 15 $\ell = 1$ modes with radial order k values ranging from 10 to 34, and 7 $\ell = 2$ modes with k values between 22 and 44. Furthermore, we detected 24 combination frequencies. We perform period-to-period fit analyses and find an asteroseismological model with mass and effective temperature that are in good agreement with those derived from spectroscopy. Seismological models allow us to estimate also the seismological distance and compare it with the precise astrometric distance measured with *Gaia*.

Initial-Final Mass Relation of Massive White Dwarfs in the Open Cluster Messier 11

Eric W. Burns, Kurtis A. Williams

Texas A&M University - Commerce, Department of Physics and Astronomy

The initial-final mass relation is a direct measure of the integrated mass loss of white dwarf progenitor stars. It provides the end state evolution of the cores of the asymptotic giant branch stars, whose models are complicated by intricate and delicate physics, especially in intermediate-mass (4-8 solar mass) progenitors. Additionally, the initial-final mass relation provides direct constraints on the upper mass limit of white dwarf progenitors. Despite significant ongoing efforts, the initial-final mass relation remains poorly constrained for intermediate-mass stars, due in large part to the steepness of the initial mass function and combination of data from multiple star clusters. Here we present initial results of a determination of the intermediate to high-mass initial-final mass relation in the rich open star cluster Messier 11. Archival data from the HST shows Messier 11 contains a well populated white dwarf cooling sequence, including candidates for ultra-massive white dwarfs. We use the HST multi-band photometry to calculate the mass and surface gravity of individual white dwarfs in the cluster, and from there determine each objects initial mass. We then describe potential implications our results have on the high-mass end of the initial-final mass relation.

Can we reveal the core-chemical composition of ultra-massive white dwarfs through their magnetic fields?

Mara Camisassa [1], Roberto Raddi [2], Leandro G. Althaus [3,4], Jordi Isern [5,6,7], Alberto Rebassa-Mansergas [2,6], Santiago Torres [2,6], Alejandro H. Córsico [3,4] and Lydia Korre [1]

[1] *Applied Mathematics Department, University of Colorado, Boulder, CO 80309-0526, USA*
[2] *Departament de Física, Universitat Politècnica de Catalunya, c/Esteve Terrades 5, 08860 Castelldefels, Spain*
[3] *Instituto de Astrofísica de La Plata, UNLP-CONICET, Paseo del Bosque s/n, 1900 La Plata, Argentina*
[4] *Facultad de Ciencias Astronómicas y Geofísicas, Universidad Nacional de La Plata, Paseo del Bosque s/n, 1900 La Plata, Argentina*
[5] *Institute of Space Sciences (ICE, CSIC), Campus UAB, Carrer de Can Magrans s/n, 08193 Barcelona, Spain*
[6] *Institut d Éstudis Espacials de Catalunya (IEEC), c/Gran Capità 2-4, Edif. Nexus 201, 08034 Barcelona, Spain*
[7] *Fabra Observatory (RACAB), Rambla dels Estudis 115, 08002 Barcelona, Spain*

Ultra-massive white dwarfs are particularly interesting objects, as they are related to type Ia Supernovae and micronovae explosions, merger events, and Fast Radio Bursts. Traditionally, ultra-massive white dwarfs were thought to harbour oxygen-neon (ONe) cores. However, recent theoretical studies and observations suggest that some ultra-massive white dwarfs could have carbon-oxygen (CO) cores. Although several studies have attempted to elucidate the core composition of ultra-massive white dwarfs, to date, it has not been possible to distinguish them through their observed properties. Here, we present a new method for revealing the core-chemical composition in ultra-massive white dwarfs that is based on the study of magnetic fields generated by convective mixing induced by the crystallization process. ONe white dwarfs crystallize at higher luminosities than their CO counterparts. Hence, the study of magnetic ultra-massive white dwarfs in the particular domain where ONe cores have reached the crystallization conditions but CO cores have not, may provide valuable support to their ONe core-chemical composition, since ONe white dwarfs would display signs of magnetic fields and CO would not. We apply our method to eight white dwarfs with magnetic field measurements and we suggest that these stars likely harbour ONe cores.

Exploring the Relationship Between the Mass and the Radius of White Dwarves

Aditya Chakrabarti [a], Agnès Bischoff-Kim [b], Aidan Lambiotte

[a] *Penn State, University Park, Pennsylvania, USA*
[b] *Penn State Scranton, Dunmore, Pennsylvania, USA*

Several methods exist for modeling or calculating the various parameters defining the properties of individual white dwarfs. In addition, in recent years the Gaia mission has provided high precision distances for thousands of white dwarfs. The purpose of this project was threefold: to measure the similarity between the data produced by the White Dwarf Evolution Code (WDEC) and Montreal White Dwarf Database (MWDD), to assess the impact of various parameters on the mass-radius relationship determined from the data, and to determine the temperature of the white dwarfs based on Gaia data and the WDEC mass-radius relation. The WDEC generates models of white dwarf stars, and models it generated were plotted against data acquired by the Gaia mission (from the MWDD) to determine how closely together the methods fit. Also, by fixing various parameters (temperature, mass of the hydrogen and helium layers, envelope mass), plots of the mass-radius relationship were obtained to assess any impact to this relation. Finally, the equation obtained by modeling the mass-radius relationship was used to calculate the temperatures using the luminosity function. These temperatures were plotted against the spectroscopic temperatures obtained from the MWDD to assess discrepancies between the two independent methods. This project showed that the WDEC models are consistent with data from the Gaia mission, and that none of the parameters chosen had any significant impact on the mass-radius relation. It was also determined that the temperature data from the MWDD was consistent with data calculated from the mass-radius relation generated using WDEC.

Newly Discovered Binary Central Stars of Planetary Nebulae from Gaia and Ground-Based Followup

Nicholas Chornay[1], Nicholas Walton[1], David Jones[2,3], Henri Boffin[4], Todd Hillwig[5], Nicole Reindl[6], Marina Rejkuba[4], Roger Wesson[7],

[1] *IoA, University of Cambridge;* [2] *IAC;* [3] *Universidad de La Laguna;* [4] *ESO;* [5] *Valparaiso University;* [6] *Universität Potsdam;* [7] *UCL*

Gaias precise photometry and repeated scanning make it a powerful tool for detecting variability across the whole sky. In planetary nebula central stars (CSPN), short-period photometric variability can be indicative of an unseen binary companion, whether through irradiation, eclipses, or tidal distortion effects. Discovering these systems - a valuable probe into the common envelope process - has been largely the result of painstaking ground-based monitoring in previous decades. With Gaia, we are able to recover most of the known close binary CSPN population by using Gaias photometric uncertainty as a proxy for variability. Not only that - we also uncover a large set of new candidate variables, which we expect to contain previously unknown binary systems. We show our method and approaches to deriving a clean candidate sample, and present new results from our ground-based campaign of followup confirmatory photometry.

Uncertainties in the 12C+12C reaction rate and their impact on the composition of ultra-massive WDs

Francisco C. De Gernimo[1,2], Marcelo M. Miller Bertolami[3], Mrcio Catelan[1,2], Tiara Battich[4]

[1] *Instituto de Astrofísica, Pontificia Universidad Católica de Chile, Av. Vicua Mackenna 4860, 7820436 Macul, Santiago, Chile*
[2] *Millennium Institute of Astrophysics, Nuncio Monseñor Sotero Sanz 100, Of. 104, Providencia, Santiago, Chile*
[3] *Instituto de Astrofísica de La Plata, CONICET-UNLP, La Plata, Argentina*
[4] *Max-Planck-Institut für Astrophysics, Karl-Schwarzschild-Strasse 1, D-85748, Garching bei München, Germany*

Ultra-massive white dwarfs (WDs) are expected to harbor oxygen-neon (ONe) or carbon-oxygen (CO) cores. Isolated ONe WDs are expected to be formed by progenitor stars with initial masses $7\,M_{\odot} \lesssim M_{\rm ZAMS} \lesssim 10\,M_{\odot}$. Stars in this mass range reach temperatures high enough to ignite C under degenerate conditions after the end of He-core burning. After the end of C-burning, the stars evolve into the so-called super AGB (SAGB) phase, ending their lives either as ultra-massive WDs or electron-capture supernovae. The exact proportions of O and Ne found in the core at the end of the SAGB phase will determine the cooling times and pulsational properties of these WDs. In this way, uncertainties affecting the nuclear reaction rates that are operative during the C burning phase are expected to have a measurable impact on the distribution of ^{16}O, ^{20}Ne, ^{23}Na, and ^{24}Mg, and consequently, on the evolution of the WD.

Here we present a study of the impact of uncertainties in the $^{12}{\rm C}(^{12}{\rm C},\alpha)^{20}{\rm Ne}$ and $^{12}{\rm C}(^{12}{\rm C},p)^{23}{\rm Na}$ nuclear reaction rates on the chemical structure of intermediate- to high-mass progenitors at the end of the C-burning phase. Using the stellar evolution code Modules for Experiments in Stellar Astrophysics (`MESA`) we computed evolutionary sequences for stars with initial masses from 7.25 to 8.25 $M_{\odot}$, from the ZAMS to the SAGB phase, adopting different prescriptions for the $^{12}{\rm C}+^{12}{\rm C}$ burning rates. Specifically, we adopted the recently reported reaction rates for carbon burning (Monpribat et al. 2022) and compared them with the results derived using the standard rates from Caughlan & Fowler (1988). We found that adopting lower reaction rates for the $^{12}{\rm C}+^{12}{\rm C}$ burning delays C-ignition by at most 2000 yrs, and that the latter takes place in a position farther from the center. We present the complete chemical profiles for selected models at the end of the C-burning phase. Our results shows that differences in the ^{20}Ne central abundances remain modest, below 13%.

The non-explosive stellar merging origin of the ultra-massive carbon-rich white dwarfs

Adela Kawka[1], Lilia Ferrario[1,2] and Stéphane Vennes[1,2]

[1] *International Centre for Radio Astronomy Research - Curtin University, GPO Box U1987, Perth, WA 6845, Australia*
[2] *Mathematical Sciences Institute, The Australian National University, Canberra, ACT 0200, Australia*

We have investigated the origin of a sub-class of carbon-polluted white dwarfs (DQ) originally identified as the "hot DQ" white dwarfs. These objects are relatively hot ($10\,000 \leq T_{\rm eff} \leq 25\,000$ K), have markedly higher carbon abundance (C-enriched) and are more massive ($M \geq 0.8\,{\rm M}_{\odot}$) than ordinary DQs, and display high space velocities. Hence, despite their young appearance, their kinematic properties are those of an old white dwarf population. The way out of this dilemma is to assume that they formed via the merging of two white dwarfs. In this paper we examine the observed characteristics of this population of "C-enriched" DQ white dwarfs and confirm that nearly half of the 63 known objects have kinematic properties consistent with those of the Galactic thick disk or halo. We have also conducted population synthesis studies and found that the merging hypothesis is indeed compatible with observations. Studies of this sub-class of white dwarfs have important implications for our understanding of Type Ia Supernovae (SNeIa), commonly used to determine the expansion history of the universe, since the same formation channel applies to both kind of objects. Hence probing the properties of these white dwarfs that failed to explode may yield important constraints to the modelling of the mechanisms leading to a thermonuclear runaway.

The Formation of High-Field Magnetic Near-Chandrasekhar Mass White Dwarfs in Binary White Dwarf Mergers

Robert Fisher[1], Sudarshan Neopane[1], Khanak Bhargava[1], Mckenzie Ferrari[1], Shin-ichiriou Yoshida[2], Silvia Toonen[3], and Eduardo Bravo[4]

[1] *Department of Physics, University of Massachusetts Dartmouth,* [2] *Department of Earth Science and Astronomy, Graduate School of Arts and Sciences, The University of Tokyo,* [3] *Anton Pannekoek Institute, University of Amsterdam,* [4] *E.T.S. Arquitectura del Vallès, Universitat Politècnica de Catalunya*

Recent observational evidence has demonstrated that white dwarf (WD) mergers are a highly efficient mechanism for mass accretion onto WDs in the galaxy. In this talk, I will explain how WD mergers naturally produce highly magnetized, uniformly rotating WDs, including a substantial population within a narrow mass range close to the Chandrasekhar mass ($M_{\rm Ch}$). These near-$M_{\rm Ch}$ WD mergers subsequently undergo rapid spin up and compression, either leading to a type Ia supernova (SN Ia) or a pure deflagration SNe Iax subluminous event. I will present a range of implications of these findings, from SNe Ia explosion mechanisms, to galactic nucleosynthesis of iron peak elements including manganese.

Post-AGB evolution in Close Binaries: Observational parameters compared to evolutionary models

Todd Hillwig; Marcelo M. Miller Bertolami; David Jones; Nicole Reindl

Valparaiso University; IALP, UNLP-CONICET; Instituto de Astrofsica de Canarias; Universität Potsdam

We compare physical parameters for the central stars of planetary nebulae (CSPNe) determined from observations and binary system modeling with theoretical values from post-AGB evolution calculations. Temperature and log g values from spectra of CSPNe can be used with post-AGB evolutionary models to determine mass and radius of the central star. Similarly, light and radial velocity curves can be used with binary modeling programs such as Phoebe to also arrive at mass and radius values. We find that, perhaps unsurprisingly, these two methods do not provide results that are in agreement. Here we discuss the differences and search for patterns that can be used in the study of future systems and which can help us understand how close binary evolution and the common envelope phase may affect post-AGB evolution.

Physical Parameters of Close Binary Central Stars of Planetary Nebulae

Todd Hillwig; David Jones; Nicole Reindl

Valparaiso University; Instituto de Astrofsica de Canarias; Universität Potsdam

Planetary nebula central stars provide a unique stage of evolution in the study of post common envelope binary systems. These systems are just out of the common envelope phase, before any additional evolution has occurred in the binary. However, given the short evolutionary time for this stage there is not a large population of such systems. Therefore, we have been working to build up a statistically significant sample of these systems both through the discovery of new close binary central stars and through the determination of physical parameters of individual systems. Here we present recent results of binary modeling for several close binary central stars of planetary nebulae. The parameters we present include masses, radii, and temperatures for each component along with orbital period, separation, and inclination of the binary system. The Phoebe binary modeling software was used to produce these values.

Oxygen opacity experiments relevant to white dwarf interiors

D.C. Mayes[1], D.E. Winget[1], M.H. Montgomery[1], B.H. Dunlap[1], J.E. Bailey[2], G.P. Loisel[2], T. Nagayama[2], T.S. Perry[3], R.F. Heeter[4], S.B. Hansen[2], T.A. Gomez[2], C.J. Fontes[3], D.P. Kilcrease[3], J. Colgan[3]

[1] *Astronomy Department, University of Texas at Austin, TX, USA*
[2] *Sandia National Laboratories, Albuquerque, NM, USA*
[3] *Los Alamos National Laboratory, Los Alamos, NM, USA*
[4] *Lawrence Livermore National Laboratory, Livermore, CA, USA*

The accuracy of opacities at stellar interior conditions has recently been called into question. These opacities are one mechanism for controlling the transfer of energy within a star toward the surface and are thus important for accurate modeling of white dwarf (WD) cooling ages. We have established experiments to investigate opacities of materials at stellar interior conditions at the Z Pulsed Power and National Ignition Facilities. Oxygen is one of the elements we are studying, which is relevant for white dwarf interiors. Previous experiments with iron revealed notable differences between theory and experiment as temperature and density were increased, resulting in an underestimate of the mean opacity. Oxygen, despite its simpler atomic structure, may also show discrepancies but due to different physics. Of particular interest is how higher densities affect the opacity spectrum and how models are handling these effects. Conditions attainable in these experiments are still much lower than some of the most important conditions for oxygen opacities in WDs but are higher than any achieved previously in the lab for opacity studies. We are experimentally accessing conditions well inside the envelopes and similar to those at the base of convection zones within these stars. Ultimately, improvements to our understanding of density effects, even at our presently attainable conditions, can affect how we model opacities at much higher temperatures and densities deeper inside WDs. This poster will discuss the experimental platforms, the methods used for diagnosing plasma conditions, and preliminary results from each platform.

This work was supported in part by the Wootton Center for Astrophysical Plasma Properties under U.S. DOE cooperative agreement number DE-NA0003843, the Fundamental Science Program of SNL, and NIFs Discovery Science Program. SNL is managed and operated by NTESS under DOE NNSA contract DE-NA0003525.

Exploring the progeny of the newly discovered CO-sdO stars

Miller Bertolami M. M.[1,2,3], Battich T.[3], Crsico A. H.[1,2], Althaus L. G.[1,2], Wachlin F. C.[1,2]

[1] *Instituto de Astrofsica de La Plata, UNLP-CONICET, La Plata, Paseo del Bosque s/n, B1900FWA, Argentina.*
[2] *Facultad de Ciencias Astronmicas y Geofsicas, UNLP, La Plata, Paseo del Bosque s/n, B1900FWA, Argentina.*
[3] *Max-Planck-Institut für Astrophysics, Karl Schwarzschild Strasse 1, 85748, Garching, Germany.*

Recently a new class of hot compact stars enriched in C and O have been discovered by Werner et al. (2022, MNRAS, Vol. 511, L66). These stars show astonishingly high surface abundances of C and O of about 20 per cent by mass fraction. These abundances are very similar to those observed in PG1159 stars, hinting at possible evolutionary connections.

In this work we present models for these new stars and study they further evolution into the PG1159 temperature domain. The new stars together with the proposed evolutionary scenario hints at the possibility that some PG1159 stars might be the result of close binary evolution.

Structure of strange dwarfs

L. Perot, N. Chamel

Universit Libre de Bruxelles, Belgium

In 1995, Glendenning et al. postulated the existence of some exotic kinds of compact stars ressembling white dwarfs but containing a very dense core made of strange quark matter. The surrounding layers consisting of a crystal lattice of nuclei in a degenerate electron sea were described by the same equation of state of Baym et al. (19971) as for the outer crust of a neutron star. In this work, we will revisit the structure of these stars using more realistic models taking into account different possible compositions.

N.K. Glendenning, C. Kettner, and F. Weber, Astrophys. J. 450, 253-261 (1995) G. Baym, C. Pethick, and P. Sutherland, Ap. J. 170, 299 (1971)

The effect of axion emission on white dwarf cooling times: a new method to constrain the axion mass

Alejandra D. Romero

Physics Institute, Universidade Federal do Rio Grande do Sul, Av. Bento Gonçalves 9500, Brazil

No abstract submitted.

Mesmerizing superoutburst of YZ Cnc

Bakowska K.[1] & Olech A.[2]

[1]*Institute of Astronomy, Faculty of Physics, Astronomy and Informatics, Nicolaus Copernicus University,*
ul. Grudziadzka 5, 87-100 Toruń, Poland
[2]*Nicolaus Copernicus Astronomical Center, Polish Academy of Sciences, ul. Bartycka 18, 00-716, Warszawa, Poland*

We present the analysis of the photometric behaviour of YZ Cancri, a SU-UMa type cataclysmic variable. Based on the data collected during the superoutburts, we constructed the $O-C$ diagram and obtained double-wave ephemeris describing the beautiful evolution of superhumps and late superhumps together.

Post superhumps maximum on intranight time scales of the AM CVn star CR Boo

Daniela Boneva[1], Radoslav Zamanov[2], Svetlana Boeva[2], Georgi Latev[2]

[1] *Space Research and Technology Institute, Bulgarian Academy of Sciences, Sofia, Bulgaria*

[2] *Institute of Astronomy and NAO, Bulgarian Academy of Sciences, Sofia, Bulgaria*

AM CVn stars are short-period binary stars, with a white dwarf accreting helium-rich material from a low-mass donor star. The AM CVn stars can manifest brightness variability, usually in a range of 2-4 magnitude at optical wavelengths. During the outbursts periods, the production of superhumps is very possible to be observed. CR Boo is a double white dwarf binary, member of AM CVn group. CR Boo periodically passes from faint to bright states, with regular or super-outburst activity.

We present observations of intranight brightness variability of CR Boo in BVR bands. The observational data are obtained with the 2m telescope of the Rozhen National Astronomical Observatory. We report appearance of superhumps, with an amplitude from 0.08 to 0.25 mag, when the maximum brightness reaches the magnitude in V band 14.08 and in B band 14.13. The secondary maximum after each superhump is detected, with the same periodicity as the superhumps: $P_{sh} = 24.76 - 24.92$ min. In our results, the post maximums are shifted in time ≈ 7.2 min, with an amplitude of ≈ 0.06 mag and an amplitude difference of 0.035 mag towards the superhumps' maximum. We find a correlation of the post maximums with the accretion processes at the outer side of the disc.

A Complete Sample of Low Mass White Dwarf Binaries in the SDSS Footprint

W. R. Brown (1), M. Kilic (2), A. Kosakowski (3), A. Gianninas (4)

(1) SAO, (2) OU, (3) TTU, (4) TC

We present the discovery of 17 double white dwarf (WD) binaries from our on-going search for extremely low mass (ELM) < 0.3 $M_\odot$ WDs. Gaia parallax provides a new means of target selection that we use to evaluate our original ELM Survey selection criteria. We identify ELM WD candidates within the 3-σ uncertainties of our original color selection. The observations complete the sample within $17 < g < 19$ mag and $-0.4 < (g - r)_0 < -0.1$ mag (approximately 9,000 K $< T_{\rm eff} <$ 22,000 K) in the SDSS footprint. Two of the newly discovered binaries have orbital periods of 22.5 min and 32 min, respectively, and are future LISA gravitational wave sources.

New clues on the formation of close white dwarf binaries with hot subdwarf companions

Stephan Geier[1], Veronika Schaffenroth[1], Ingrid Pelisoli[2], Thomas Kupfer[3], Brad Barlow[4], Matti Dorsch[5], Nicole Reindl[1], Uli Heber[5], Andreas Irrgang[5], et al.

[1]*Institut für Physik und Astronomie, Universität Potsdam, Haus 28, Karl-Liebknecht-Str. 24/25, D-14476 Potsdam-Golm, Germany*
[2]*Department of Physics, University of Warwick, Coventry, CV4 7AL, UK*
[3]*Texas Tech University, Department of Physics & Astronomy, Box 41051, 79409, Lubbock, TX, USA*
[4]*Department of Physics, High Point University, One University Parkway, High Point, NC, 27268, USA*
[5]*Dr. Karl Remeis-Observatory & ECAP, Astronomical Institute, Friedrich-Alexander University Erlangen-Nuremberg, Sternwartstr. 7, D-96049 Bamberg, Germany*

About one third of the single-lined hot subdwarf B (sdB) stars in the field are found in close binaries with unseen companions. The majority of those post-common envelope systems consists of sdBs in close orbits around white dwarfs (WDs). The analysis of new data from large space-based light curve (TESS, Kepler, K2) and ground-based spectroscopic (SDSS, LAMOST) surveys allowed us to characterize the population of sdB+WD binaries in much more detail. Here we present updated constraints on binary fractions and the fundamental parameters of those binaries. Based on this new observational evidence, we come to the conclusion that several different evolutionary paths are needed to explain the population of sdB+WD binaries.

Ellipsoidal Binaries with Compact Companions Hidden in TESS

Matthew J. Green, Dan Maoz, Tsevi Mazeh, Simchon Faigler, Sahar Shahaf

Tel Aviv University, Israel; Weissman Institute, Israel

Binaries with small orbital separations display photometric signatures that result from the tidal distortion of their component stars. These signatures can be used to identify candidate non-eclipsing binary systems. We used the BEER algorithm (Faigler et al. 2011, 2013, 2015a, 2015b) and TESS data to select 13.000 candidate binaries with orbital periods < 5 days, with a purity of ≈ 85 percent. This is the largest sample of binary systems in this period range.

In this poster we will discuss the implications of this sample for compact binary research. Among the sample are certain to be a number of main sequence + white dwarf binaries, in particular post-common envelope binaries with AFGK primaries, which are otherwise difficult to identify due to the bright primary star. We will present an overview of this sample, including preliminary attempts to identify white dwarf companions, and discuss possible future work in the area of white dwarf binaries using this sample.

Constraining ELM White Dwarf stars exhibiting ellipsoidal variations with MCMC

Thomas N. Hemphill
Keaton J. Bell

Department of Astronomy, University of Washington, Seattle, WA-98195, USA

We constrain the physical characteristics of extremely low-mass white dwarf stars in tight binary systems that exhibit photometric ellipsoidal variations from tidal distortion with a Markov Chain Monte Carlo analysis. These variations allow us to constrain the orbital inclination and secondary mass that are typically ambiguous in single-lined spectroscopic binaries. We combine data from multiple surveys to benefit from the advantages of each data set, including Gaia astrometry measurements, lightcurves provided by the TESS, ASAS-SN, and ZTF surveys, and radial velocity measurements provided from the ELM Survey. This poster presents our current progress in this effort, indicating current challenges and future directions for the work.

Solving the cunundrum of circumbinary companion vs dynamo-induced orbital period variations

Frederic V. Hessman

Institut für Astrophysik, Georg-August-Universität Göttingen

Quasi-sinusoidal orbital period variations in post-common envelope WD binaries can be explained as being due to the presence of circumbinary companions and/or to spin-orbit coupling due to dynamo activity in the secondary stars (Applegate/Lanza mechanisms). Since many systems cannot be reproduced using circumbinary companions alone, we know that the latter process is certainly at work, although it is poorly understood. On the other hand, we also know that planetary debris exists around single WD and that transiting planets exist around pre-common envelope binaries, making the model of circumbinary companions quite plausible. I will show that there is a way out of this conundrum and propose a global campaign to solve this problem principally once and for all.

Light curve modelling and Doppler tomography of AY Psc

J. Kára[1], S. Zharikov[2,3], M. Wolf[1], A. Amantayeva[3], G. Subebekova[3], S. Khokhlov[3], A. Agishev[3] and J. Merc[1,4]

[1] *Astronomical Institute, Faculty of Mathematics and Physics, Charles University, V Holešovičkách 2, 180 00 Praha 8, Czech Republic,*
[2] *Universidad Nacional Autónoma de México, Instituto de Astronomía, AP 106, Ensenada, 22800, BC, México*
[3] *Al-Farabi Kazakh National University, Al-Farabi Ave., 71, 050040, Almaty, Kazakhstan*
[4] *Institute of Physics, Faculty of Science, P. J. Šafárik University, Park Angelinum 9, 040 01 Košice, Slovak Republic*

AY Psc is an eclipsing cataclysmic variable of Z Cam-type. We have obtained time-resolved photometric observations in different stages of activity and time-resolved spectroscopic observations during standstill. We applied our light curve modelling techniques and the Doppler tomography method to analyse the obtained data. We determined the fundamental parameters of the system and the structure of the accretion flow therein. We constructed a Doppler map of the system based on the Hα emission line, which shows that the line is a superposition of radiation from the irradiated surface of the secondary, from the flux of the outflow zone, and winds which originate in the hot spot and the central part of the accretion disk.

A well-resolved compact double-lined double-degenerate eclipsing binary in ZTF

Alekzander Kosakowski[1]

[1]*Department of Physics and Astronomy, Texas Tech University, Lubbock, TX 79409, USA*

No abstract submitted.

Characterization of the accretion disc in V1040 Cen

Sebastian Kurowski[1], Linda Schmidtobreick[2], Waclaw Waniak[1], Artur Rutkowski[3]

[1]*Astronomical Observatory of the Jagiellonian University, Krakow, Poland;* [2]*ESO, Vitacura, Chile;*
[3]*Institute of Meteorology and Water Management - National Research Institute, Krakow, Poland*

V1040 Cen is a high inclination, non-eclipsing dwarf nova. We observed it with the High Resolution Spectrograph on the South African Large Telescope (SALT), covering the whole orbital period. Using diagnostic diagram method we recovered orbital parameters of the system like phase zero, semi-amplitude of the primary's radial velocity and the systemic velocity. We reconstructed brightness maps of the accretion disc in the Hydrogen and Helium emission lines using Doppler tomography technique. Using the same methods, we also analized the archival dataset from VLT UVES, which was obtained 10 years before our SALT observations. This allowed us to compare our results between these two observing periods.

Photometric monitoring of eclipsing dwarf novae using two robotic telescope networks

Sebastian Kurowski[1], Waclaw Waniak[1], Linda Schmidtobreick[2]

[1]*Astronomical Observatory of the Jagiellonian University, Krakow, Poland;* [2]*ESO, Vitacura, Chile*

Eclipsing dwarf novae are considered to be the perfect laboratories to study accretion. As high inclination systems, they allow to reconstruct a brightness distribution across an accretion disc using indirect techniques like Doppler tomography or eclipse mapping. However, such observations are very challenging. High quality data from large telescopes is needed and it is difficult to predict variability of dwarf novae (semi-periodic outbursts, superoutbursts or standstills). In order to select the most interesting and suitable targets for such observations, I performed a photometric monitoring program of bright, eclipsing dwarf novae. To cover both the northern and southern hemispheres, as well as obtain sufficient time resolution, I used two networks of robotic telescopes with diameters around 0.5 m iTelescope and Skynet. In the poster I will present characteristics of both networks as well as preliminary results for the most interesting targets.

A Hot Subdwarf Model for the 18.18 minutes Pulsar GLEAM-X

Dan Maoz and Avi Loeb

Tel-Aviv University, Harvard University

We suggest that the recently discovered, enigmatic pulsar with a period of 18.18 minutes, GLEAM-X J162759.5-523504.3, is most likely a hot subdwarf (proto white dwarf). A magnetic dipole model explains the observed period and period-derivative for a highly magnetized ($\sim 10^8$ G), hot subdwarf of typical mass $0.5\mathrm{M}_\odot$ and radius $0.3\mathrm{R}_\odot$, and an age of $\sim 310^4$ yr. The subdwarf spin is close to its breakup speed and its spindown luminosity is near its Eddington limit, likely as a result of accretion from a companion.

The impact of nova eruptions on the white dwarf

Linda Schmidtobreick[1], Lientur Celedon[2], Fernando Selman[1], Mike Shara[3], Claus Tappert[2]

[1] *ESO Chile, Vitacura*
[2] *Universidad de Valparaiso*
[3] *AMNH, New York*

A nova eruption in a cataclysmic variable (CV) is a thermonuclear explosion on the surface of the white-dwarf primary once it has accreted a critical mass from its late-type companion. Between these eruptions, the binary is supposed to appear as a 'normal' CV, although theories predict that for the first tens or hundreds of years, the white dwarf is still heated up which might influence the mass-transfer rate of the binary.

To study the effect of the nova eruption on the white dwarf, we have conducted a long-term project to recover old novae and to study the binary within. The results show indeed that for the vast majority of old novae, the white dwarf is hot and mass transfer is high. Very few examples exist where a possible cooling of the white dwarf is observed and for any decent statistic, we need to find more novae that are at least a few hundred years old. We are conducting a deep, wide-field Hα + [NII] survey of cataclysmic variables to search for remnant nova shells, tell-tale signs of ancient novae. Here we summarise the results of the search and discuss the detections and non-detections in the context of CV evolution.

A new grid of LTE model atmospheres for hot white dwarfs and its application to CAL 83 and RX J0513.9−6951

V. Suleimanov, V. Doroshenko, T. Rauch, A. Tavleev, and K. Werner

Institut für Astronomie und Astrophysik, Kepler Center for Astro and Particle Physics, Universität Tübingen, Sand 1, D-72076 Tübingen, Germany

We present a new grid of plane-parallel hot white dwarf (WD) model atmospheres designed for modeling of the high-resolution X-ray spectra of super-soft sources (SSSs) in the Large Magellanic Cloud (LMC).

The models were computed using the LMC chemical composition, namely solar H/He mix and the half solar heavy element abundances. We construct a two-parameter model grid with the effective temperature $T_{\rm eff}$ and $\Delta \log g = \log g - \log g_{\rm Edd}$ characterizing the distance of a given grid point from the Eddington limit as free parameters. We consider the 15 most abundant chemical elements and about 20 000 spectral lines from the CHIANTI database for spectroscopic diagnostics of astrophysical plasmas to calculate model spectra for each point. We convert the grid into XSPEC atable format models and employed it to approximate Chandra LETG spectra of two well studied SSSs, namely CAL 83 and RX J0513.9−6951 to estimate consistently the WD's parameters. In particular, we impose an additional relation gf mass M and radius R suggested by Suleimanov & Ibragimov (2003), $R = 2R_{\rm cold}(M_\odot/M)^2$, where $R_{\rm cold}$ is the radius of the cold WD with the given mass M.

We compare the results with previous NLTE modeling of hot WDs and discuss the advantages and limitations of our newly calculated grid.

Complex precession behaviour of the V603 Aql accretion disc in 2020-2021.

C. Belyakov[1], G. Sjoberg[2], V. Neustroev[3], V. F. Suleimanov[4]

[1] *"Parallax" Enterprise, Kazan, Russia*
[2] *AAVSO*
[3] *Space Physics and Astronomy Research Unit, PO Box 3000, 90014, University of Oulu, Finland*
[4] *Institut für Astronomie und Astrophysik, Kepler Center for Astro and Particle Physics, Universität Tübingen, Sand 1, D-72076 Tübingen, Germany*

Bright novalike cataclysmic variable V603 Aql demonstrates volatile photometric behaviour with a variable photometric period between slightly larger and slightly smaller than the orbital period of the system ($P_{\rm orb} \approx 0.1385$ d). These changes were interpreted before as a positive or negative accretion disc precession. Here we present unprecedentedly long amateur photometric observations of V603 Aql in 2020 (45 nights during 66 days) and in 2021 (35 nights during 103 days). These long-duration observations allow us to investigate directly photometric changes connected with the accretion disc precession. We found that the accretion disc in 2020 exhibited a long negative precession period of 26.5±4.5 days, directly visible in a power spectrum.The corresponding photometric period 0.13785 d, which is slightly shorter than the orbital period was also observed. The accretion disc precession became more complex in 2021. Three long photometric periods of 20.4±4 d, $10.8^{+1.8}_{-0.8}$ d, and 6.8±0.6 d were directly observed. We interpret the first period as a positive (in the same direction as the orbital motion) elliptical disc precession and the second one as a negative (in the opposite direction in comparison with the orbital motion) precession of the inclined disc. The third period which has the largest significance is connected with the first two as $P_3^{-1} = P_1^{-1} + P_2^{-1}$. The corresponded beat periods with the orbital period were also found – 0.1397 d, 0.13655 d, and 0.1417 d.

Searching for binary star candidates with a white dwarf component in the Gaia DR3

George Thomas

University of Leicester

Obtaining large samples of spatially unresolved double degenerates (DDs) from photometric catalogues like Gaia DR3 is challenging because the cooling curves of single and binary white dwarfs overlap on colour-colour diagrams. This is also true for the elusive type 1a supernova progenitors (SNIa) which, according to the DD channel of SNIa detonation, consist of a pair of closely orbiting white dwarfs whose total mass is constrained by the Chandrasekhar limit of $1.4M_{\odot}$. However, C/O core DDs with low mass constituents will be over-luminous compared to their single counterparts, which makes it possible to select DD candidates from Gaias high precision parallax and photometry data. According to the white dwarf mass distribution, single white dwarfs are relatively few in number at masses below $0.45M_{\odot}$. Therefore, any white dwarfs that lie above the corresponding cooling curve on the H-R diagram are likely to be double white dwarf systems. The population of SNIa progenitor candidates can be constrained by a binary cooling curve corresponding to equal mass constituents of $0.7M_{\odot}$. White dwarf binaries that lie above this line on the H-R diagram are unlikely to have masses that are consistent with the Chandrasekhar limit. Additional constraints on DD candidates can be considered by appealing to the Gaia astrometric error statistics, like the renormalized unit weight error (RUWE), which may be large for unresolved astrometric binaries. Using these constraints in the search for DDs may significantly reduce the amount of telescope observation time required to identify these objects compared to blind surveys, such as the Type Ia Supernova Progenitor Survey (SPY). The DR3 binary catalogues will also provide useful information on the photometric properties of DDs, as these will serve as references for white dwarf binaries in DR3. We intend to select a large sample of white dwarfs from DR3 with astrometric and photometric cuts that are carefully designed to put a heavy bias on DD systems. We will then follow up on this catalogue with multi-epoch spectroscopy to obtain the orbital periods of any confirmed double degenerates, with an eye to identify SNIa progenitors.

Revisiting the White Dwarf in the extraordinary Cataclysmic Variable V455 Andromedae.

Gagik Tovmasian[1], Anna Francesca Pala[2], Sergei Zharikov[1], Vitaly Neustroev[3], Elmé Breedt[4], Boris Gänsicke[5]

[1]*Instituto de Astronomía, Universidad Nacional Autónoma de México, Aptdo Postal 106, Ensenada, Baja California, C.P. 22800, Mexico.*
[2]*European Space Agency, European Space Astronomy Centre, Camino Bajo del Castillo s/n, 28692 Villanueva de la Caada, Madrid, Spain*
[3]*Space Physics and Astronomy Research Unit, PO Box 3000, 90014 University of Oulu, Finland*
[4]*Institute of Astronomy, University of Cambridge, Cambridge, CB3 0HA, UK*
[5]*University of Warwick, Department of Physics, Gibbet Hill Road, Coventry, CV4 7AL, United Kingdom.*

V455 And is a dwarf nova of WZ Sge type located at the period minimum of the orbital period distribution of Cataclysmic Variables. V455 And shows a great number of variabilities, many of which are of periodic nature. However, it is not yet clear what physical processes produce some of them and how they influence each other. We collected huge observational material and assessed several properties of this extraordinary object anew.

What can photometrical observations of eclipsing binaries tell us about physical parameters of these systems

Irina Voloshina

Sternberg Astronomical institute, Lomonosov Moscow State university, RF

No abstract submitted.

Search for the short-period variability in SS Cyg system based on new data

Irina Voloshina, Tatiana Khruzina and Vladimir Metlov

Sternberg Astronomical institute, Lomonosov Moscow State university, RF

The results of photometric observations of the well-known dwarf nova, the SS Cyg X-ray source, conducted in 2019–2021 are presented. Observations were made at various moments of the outburst cycle using several CCD cameras on two telescopes, 50 and 60-cm (about 47,000 measurements). Based on the data obtained, the system's light curves in filters V, R were constructed. According to the new data, the orbital period SS Cyg was determined, the value of which turned out to be 0.4% less than previously determined by Voloshina & Lyutyi (1992). The search for photometric variability, carried out after taking into account the orbital variability of SS Cyg, made it possible to detect pulsations on the light curves and determine their periods amplitudes. The analysis of the obtained values of the periods and amplitudes of pulsations allowed us to reveal the dependencies of these values on the brightness of the system at the stage of the brightness decrease after the maximum, - there is a clear increase in the period of pulsations with a decrease in the radiation flux. With a decrease in brightness, their amplitude also increases, i.e., as SS Cyg returns to normal brightness after an outburst. At the end of April 2020 SS Cyg had an X-ray outburst. The results of optical photometry conducted in May 2020 at the end of this outburst and later in 2021 show that the behavior of SS Cyg after the end of the X-ray outburst fits into the framework of the usual behavior of the system at this stage of the outburst cycle.

Mass Transfer and Accretor Cooling in AM CVn binaries

Tin Long Sunny Wong[1] & Lars Bildsten[1,2]

[1] *Department of Physics, University of California, Santa Barbara, CA 93106, USA*
[2] *Kavli Institute for Theoretical Physics, University of California, Santa Barbara, CA 93106, USA*

AM CVn binaries are ultracompact with $P_{\rm orb} \approx 5-70$ minutes undergoing helium mass transfer. I will describe results using MESA to model the mass transfer from an initially $< 0.2\,M_\odot$ He WD onto an initially $> 0.6\,M_\odot$ CO WD. In agreement with previous works, the initially high mass transfer rate forces an adiabatic evolution of the donor for $P_{\rm orb} < 30$ minutes, such that its mass-radius relation (and hence mass-orbital period relation) depends primarily on its initial entropy. At later times, entropy loss occurs, but at an uncertain rate due to unreliable cool helium opacities. The thermal evolution of the accretor, however, is more certain. The CO WD is reheated at early times due to the very rapid accretion and then evolves, as the accretion rate declines, to a cooling phase at $P_{\rm orb} > 30$ minutes. Given a relation between orbital period and cooling time of the accretor, assuming adiabatic evolution of the donor, we find that the observed accretors at long orbital periods are not as cool as expected. The discrepancy widens if entropy loss of the donor is allowed. We speculate this cooling delay may have the same physical origin of a similar delay seen in massive WDs in the field.

4 Participants

Amorim	larissal.pesquisa@gmail.com	Brazil
Andreiievskyi	andrievskii@ukr.net	Ukraine
Antunes Amaral	larissa.amaral@postgrado.uv.cl	Chile
Badenas Agusti	mbadenas@mit.edu	USA
Bagnulo	stefano.bagnulo@armagh.ac.uk	UK
Bakowska	Bakowska@umk.pl	Poland
Barrientos	mbarrientos@ou.edu	USA
Barstow	mab@le.ac.uk	UK
Battich	tiara@mpa-garching.mpg.de	Germany
Bauer	evan.bauer.astro@gmail.com	USA
Bédard	antoine.bedard@umontreal.ca	Canada
Bell	keatonb@uw.edu	USA
Berbel	zethran.berbel@austin.utexas.edu	USA
Bischoff-Kim	axk55@psu.edu	USA
Blouin	sblouin@uvic.ca	Canada
Bognar	bognar.zsofia@csfk.org	Hungary
Boneva	danvasan@space.bas.bg	Bulgaria
Boston	rboston@live.unc.edu	USA
Brooks	beau_brooks@baylor.edu	USA
Brown	ajbrown2@sheffield.ac.uk	UK
Brown	wbrown@cfa.harvard.edu	USA
Bues	bues@sternwarte.uni-erlangen.de	Germany
Burleigh	mrb1@le.ac.uk	UK
Burmester	uri.burmester@anu.edu.au	Australia
Burns	eburns1@leomail.tamuc.edu	USA
Caiazzo	ilariac@caltech.edu	USA
Calcaferro	leilacalcaferro@gmail.com	Argentina
Camisassa	camisassam@gmail.com	USA
Caron	alexandre.c66@hotmail.com	Canada
Casewell	slc25@le.ac.uk	UK
Castanheira	barbara_endl@baylor.edu	USA
Chakrabarti	katchakra01@gmail.com	USA
Cheng	s.cheng@jhu.edu	USA
Chickles	echickle@mit.edu	USA
Cho	patricia.cho@utexas.edu	USA
Chornay	nickchornay@gmail.com	UK
Córsico	alejandrocorsico@gmail.com	Argentina
Cukanovaite	E.Cukanovaite.1@warwick.ac.uk	UK
Cunningham	timothy.cunningham@warwick.ac.uk	UK
Cutolo	anna-maria.cutolo@warwick.ac.uk	UK
Dawson	harry.b.a.dawson@gmail.com	Germany
De Geronimo	degeronimofrancisco@gmail.com	Chile
Dorsch	mattidorsch@icloud.com	Germany
Dufour	patrick.dufour@umontreal.ca	Canada
Dunlap	bhdunlap@utexas.edu	USA
El-Badry	kareem.el-badry@cfa.harvard.edu	USA
Elms	abbigail.elms@warwick.ac.uk	UK

Farihi	j.farihi@ucl.ac.uk	UK
Ferrario	lilia.ferrario@anu.edu.au	Australia
Filiz	filiz@astro.uni-tuebingen.de	Germany
Fisher	robert.fisher@umassd.edu	USA
Gamrath	sebastien.gamrath@umons.ac.be	Belgium
Gänsicke	Boris.Gaensicke@warwick.ac.uk	UK
Geier	sgeier@astro.physik.uni-potsdam.de	Germany
Gentile Fusillo	ngentile@eso.org	Germany
Ginzburg	sivan.ginzburg@mail.huji.ac.il	USA
Green	mjgreenastro@gmail.com	Israel
Guidry	jaguidry@bu.edu	USA
Hallakoun	naama.hallakoun@weizmann.ac.il	Israel
Hardy	francois.hardy.1@umontreal.ca	Canada
Heber	ulrich.heber@fau.de	Germany
Heintz	tmheintz@bu.edu	USA
Hemphill	tnhemphill@gmail.com	USA
Hermes	jjhermes@bu.edu	USA
Hessman	fhessma@uni-goettingen.de	Germany
Hillwig	Todd.Hillwig@valpo.edu	USA
Hobbs	brycehobbs@utexas.edu	USA
Hollands	m.hollands@sheffield.ac.uk	UK
Huegel	isaac.huegel@austin.utexas.edu	USA
Inight	Keith.Inight@warwick.ac.uk	UK
Irawati	puji.irawati@narit.or.th	Thailand
Isern	isern@ice.csic.es	Spain
Izquierdo	Paula.Izquierdo-Sanchez@warwick.ac.uk	UK
Jeffery	simon.jeffery@armagh.ac.uk	UK
Jeffery	ejjeffer@calpoly.edu	USA
Jordan	jordan@ari.uni-heidelberg.de	Germany
Kaiser	ben.kaiser@unc.edu	USA
Kao	mlkao@utexas.edu	USA
Kára	honza.kara.7@gmail.com	Czech Republic
Kepler	kepler.oliveira@gmail.com	Brazil
Koester	koester@astrophysik.uni-kiel.de	Germany
Korčáková	kor@sirrah.troja.mff.cuni.cz	Czech Republic
Korol	korol.valeria@gmail.com	UK
Kosakowski	alekzander.kosakowski@ttu.edu	USA
Kovtyukh	vkovtyukh@ukr.net	Ukraine
Kowalski	p.kowalski@fz-juelich.de	Germany
Kumar	pkumar5@crimson.ua.edu	USA
Kurowski	sebastian@oa.uj.edu.pl	Poland
Lagos	felipe.lagos@postgrado.uv.cl	UK
Lam	lam@mail.tau.ac.il	Israel
Landstorfer	alex.landstorfer@gmail.com	Germany
Landstreet	John.Landstreet@Armagh.ac.uk	Canada
Littlefair	s.littlefair@shef.ac.uk	UK
López-Sanjuan	clsj@cefca.es	Spain
Lynas-Gray	aelg@astro.ox.ac.uk	UK
Maldonaldo	raul.maldonado@uam.es	Spain
Malyshev	denys.malyshev@astro.uni-tuebingen.de	Germany

Mander	cm775@leicester.ac.uk	UK
Manjunatha Rao	reshma.manjunatha-rao@student.uni-tuebingen.de	Germany
Manser	c.j.manser92@googlemail.com	UK
Maoz	profdanmaoz@gmail.com	Israel
Marsh	t.r.marsh@warwick.ac.uk	UK
Martinez	zmartinez5@leomail.tamuc.edu	USA
Mayes	dmayes@utexas.edu	USA
Miller	drmiller@phas.ubc.ca	Canada
Miller Bertolami	mmiller@fcaglp.unlp.edu.ar	Argentina
Mohandasan	anjmohnvp@gmail.com	Italy
Montgomery	mikemon@astro.as.utexas.edu	USA
Moraga Merino	rodrigo.moraga-merino@student.uni-tuebingen.de	Germany
Moss	adam.g.moss-1@ou.edu	USA
Munday	james.munday@warwick.ac.uk	UK
Muñoz Giraldo	munoz-giraldo@astro.uni-tuebingen.de	Germany
Neustroev	Vitaly.Neustroev@oulu.fi	Finland
O'Brien	Mairi.O-Brien@warwick.ac.uk	UK
Okuya	ayaka.okuya@nao.ac.jp	Japan
Ould Rouis	lbor@bu.edu	USA
Pala	annafpala@gmail.com	Spain
Parker	quentinp@hku.hk	Hongkong
Parsons	s.g.parsons@sheffield.ac.uk	UK
Parvatikar	parvatikar.manali@gmail.com	Germany
Patel	shreya.patel@student.uni-tuebingen.de	Germany
Pelisoli	ingrid.pelisoli@warwick.ac.uk	UK
Perot	loic.perot@ulb.be	Belgium
Poggiani	rosa.poggiani@unipi.it	Italy
Pritzkuleit	maxpri@astro.physik.uni-potsdam.de	Germany
Provencal	jlp@udel.edu	USA
Queitsch	queitsch@astro.uni-tuebingen.de	Germany
Raddi	roberto.raddi@upc.edu	Spain
Rajamuthukumar	abinaya@mpa-garching.mpg.de	Germany
Ramirez	sergio.ramirez-ramirez@warwick.ac.uk	UK
Rauch	rauch@astro.uni-tuebingen.de	Germany
Rawat	rawatnikita221@gmail.com	India
Rebassa-Mansergas	alberto.rebassa@upc.edu	Spain
Reindl	nreindl885@gmail.com	Germany
Rogers	lr439@cam.ac.uk	UK
Romero	aleromero82@gmail.com	Brazil
Sahu	snehalatash30@gmail.com	UK
Saumon	dsaumon@lanl.gov	USA
Schaffenroth	schaffenroth@astro.physik.uni-potsdam.de	Germany
Schmidtobreick	lschmidt@eso.org	Chile
Schreiber	matthias.schreiber@usm.cl	Chile
Shen	kenshen@astro.berkeley.edu	USA
Słowikowska	aga@umk.pl	Poland
Sowicka	paula@camk.edu.pl	Poland
Stelzer	stelzer@astro.uni-tuebingen.de	Germany
Stopkowicz	stella.stopkowicz@uni-mainz.de	Germany
Suleimanov	suleimanov@astro.uni-tuebingen.de	Germany

Swan	Andrew.Swan@warwick.ac.uk	UK
Tavleev	tavleev@astro.uni-tuebingen.de	Germany
Thomas	gt155@leicester.ac.uk	UK
Toloza	odette.toloza@usm.cl	Chile
Torres	santiago.torres@upc.edu	Spain
Tovmasian	gag@astro.unam.mx	Mexico
Townsley	Dean.M.Townsley@ua.edu	USA
Tremblay	P-E.Tremblay@warwick.ac.uk	UK
Tremblay	patrick.tremblay.12@umontreal.ca	Canada
Ugalino	mugalino@umassd.edu	USA
Uzundag	murat.uzundag@postgrado.uv.cl	Chile
van Roestel	jcjvanroestel@gmail.com	USA
Vanderbosch	zvanderb@caltech.edu	USA
Vani	akashdvani@gmail.com	Germany
Vauclair	gerard.vauclair@irap.omp.eu	France
Viaña	vianajr@mit.edu	USA
Vincent	o.vincent@umontreal.ca	Canada
Voloshina	voloshina.ira@gmail.com	Russia
Wajid	wajid@astro.uni-tuebingen.de	Germany
Walters	nikolay.walters.15@ucl.ac.uk	UK
Wangnok	kittipong.wangnok@gmail.com	Thailand
Weich	sebastian.weich@fau.de	Germany
Werner	werner@astro.uni-tuebingen.de	Germany
White	jacksonwhite@utexas.edu	USA
Williams	Kurtis.Williams@tamuc.edu	USA
Winget	dew@astro.as.utexas.edu	USA
Wong	tinlongsunny@ucsb.edu	USA
Zakamska	zakamska@jhu.edu	USA

5 Code of Conduct

The community of participants at astronomical meetings and in astronomical research is made up of members from around the globe with a diverse set of skills, personalities, and experiences. It is through these differences that our community experiences success and continued growth. We expect everyone in the EuroWD community to follow the guidelines outlined below when interacting with others both apart of and separate from the EuroWD meeting. Our goal is to maintain a positive, inclusive, successful, and growing scientific community.

As members of the community,
We pledge to treat all people with respect and provide a harassment and bullying-free environment, regardless of sex, sexual orientation and/or gender identity, disability, physical appearance, body size, race, nationality, ethnicity, and religion. In particular, sexual language and imagery, sexist, racist, or otherwise exclusionary jokes are not appropriate.

We will treat those outside our community with the same respect as people within our community. We pledge that all discussions between members of the community should be done with respect, and we pledge to take proactive measure to ensure that all participants are heard and feel confident that they can freely express their opinions. We pledge to help the entire community follow the code of conduct and to act accordingly when we note violations.

This Code of Conduct applies to all situations during EuroWD, including official conference events, associated social events, on social media, and one-on-one interactions.

The EuroWD organizers reserve the right to enforce this Code of Conduct and will take necessary action to keep EuroWD a welcoming environment for all participants.

Reporting Violations
If at any time you feel like a violation of this Code of Conduct has occured, or in general feel unsafe or unwelcome at our conference, please let us know using one of the following ways to report your concern:
In person: reporting to one of the following organizers: Thomas Rauch and Klaus Werner. When taking a personal report, we will ensure you are safe and cannot be overheard. Once safe, we'll ask you to tell us about what happened. This can be upsetting, but we will handle it as respectfully as possible, and you can bring someone to support you. You won't be asked to confront anyone.
Via email: to our local organizing committee: astro-eurowd20@listserv.uni-tuebingen.de
Via phone: +49 173 8767831 or +49 176 32463007