'Binary stars: Current developments and preparing for future missions (BinStars)' Abstracts

Talks

From single to double-lined: absolute, dynamical masses using HRCCS

Authors

Adam Stevenson (1), Yasmin Davis (1), Amaury Triaud (1)

(1) University of Birmingham

Abstract

High contrast ratio eclipsing binary systems provide an opportunity to probe mass-radius relations for low-mass stars. Being single-lined, secondary parameters are ultimately dependent on stellar models. Using novel high-resolution cross-correlation techniques on optical spectra, we can now extract the weak signal of the secondary and determine its semi-amplitude. This turns the system into a double-lined eclipsing binary, allowing for absolute dynamical masses to be calculated. I will present results for targets in the EBLM project, where we measure the masses of ~0.2 Msun secondary companions with accuracy of 1-2%. EBLM targets are eclipsing binaries comprised of F/G + M-type stars, with a typical flux ratio of 10^-4. I will also compare absolute to modelled secondary and primary masses, demonstrating that single-lined results can be as reliable as double-lined binaries. These results help glean understanding of the M-dwarf domain, where parameters are often poorly constrained.

Stellar merger remnants: Varied morphologies and complex chemistry

Authors
Thomas Steinmetz (1)

(1) Nicolaus Copernicus Astronomical Center

Abstract
Stellar mergers within non-compact binary systems, also known as Luminous Red Novae (LRNe), are a rare but unusual phenomenon. Such mergers can involve stars ranging between pre-main sequence stars to involved red supergiants and (post-)AGB stars. The eruption that arises from the merger event exceeds several orders of magnitude, and features multiple peaks or plateaus in the flux, before the luminosity decreases to below the progenitor brightness. The remnants of these mergers appear as cool, inflated stars, surrounded by a circumstellar environment dominated by dust and molecular gas. Therefore, LRNe are typically bright at infrared and sub-millimetre wavelengths, and faint at optical wavelengths.

Although extensive work has been done to examine and model LRNe during the progenitor and eruption phases, the evolution of a merger remnant is not well understood. The post-merger properties, including the stellar and circumstellar characteristics, are similar to those of evolved stars such as RSG and AGB stars, as well as some bipolar planetary nebulae. However, some unusual characteristics, such as the chemical composition of the circumstellar gas and dust, as well as the morphologies, may provide useful identifying features that help us distinguish LRNe from more typical evolved stars. In particular, the observation of CrO and the radioactive isotope 26-Al has not yet been observed in any astrophysical source other than LRNe.

In this talk, I will give an overview of the various observational features of Galactic LRNe, including the varied morphologies, the unusual chemical features observed in both the gas and dust, and the efforts to examine the evolution of the post-merger remnant. I will also discuss the potential for identifying LRNe at later times, years after the merger event, and present a list of potential merger remnant candidates that have been speculated in the literature.

High precision stellar astrophysics with eclipsing binary stars (Invited)

Authors

Pierre Maxted (1)

(1) Keele University

Abstract

Detached eclipsing binary stars are currently our best source of accurate and precise fundamental data for normal stars. I will review the developments in instrumentation and observational techniques that have led to an order-of-magnitude improvement in the precision and mass and radius measurements over the past 20 years. I will also review new observational techniques that can provide additional data that will help to better calibrate free parameters in stellar evolution models.

Yields of the "holy grail" neutron deficient isotopes of molybdenum and ruthenium in neutron star common envelopes

Authors

Sophie Abrahams (1), Alison Laird (1), Christian Diget (1), Chris Fryer (2), Alexander Hall-Smith (1)

(1) University of York
(2) Los Alamos National Laboratory

Abstract

During common envelope evolution between a neutron star and a companion star, the neutron star can accrete material from the companion's stellar envelope at hyper-Eddington accretion rates. The proton rich accreting material has angular momentum and so hangs up in an accretion disk, creating a unique scenario for nucleosynthesis. Studies have found that some fraction of the accreted material will be ejected back into the stellar envelope. At the end of common envelope evolution, this material will re-enter the interstellar medium and contribute to galactic chemical evolution.

Yields from a set of neutron star common envelopes have been calculated by combining STARTRACK binary population data, MESA stellar models and results of nuclear post processing. These yields show that neutron star common envelopes are able to eject the elusive neutron deficient isotopes 92, 94Mo and 96,98Ru, and that this astrophysical site may be able to account for a significant fraction of the galactic mass of these isotopes. This is of great interest to the nuclear astrophysics community, as the production site for these isotopes is unconfirmed and they are underproduced in current p-process models.

We will compare our model to previous in the field, highlighting the developments in our work. We will present yields calculated from neutron star common envelopes, discussing the number of neutron star common envelopes required to account for the total galactic mass of 92Mo and 96,98Ru. We will introduce potential gamma-ray observable isotopes from neutron star common envelopes. We will discuss constraints on our models, with emphasis placed on the importance of understanding the binding energy of the envelope.

Challenges to the Classical Treatment of Massive Binary Interactions from Observed Stripped Stars in Binaries

Authors

Dandan Wei (1), Ylva Götberg (1)

(1) Institute of Science and Technology in Austria

Abstract

Intermediate-mass stripped stars, with current masses between 2 and 8 Msun, are key progenitors of stripped-envelope supernovae and play an essential role in forming gravitational wave mergers. The recent discovery of hot, intermediate-mass stripped stars provides valuable benchmarks for studying the direct products of binary interactions. Multi-epoch spectroscopical observations have enabled us to determine the orbital solutions for six stripped-star binaries, revealing periods from hours to years. By combining analytical methods with stellar models from the binary stellar evolution code MESA, we explore their evolutionary pathways and constrain long-standing uncertainties in binary evolution, particularly common-envelope interaction and mass transfer. Assuming the progenitors of short-period stripped star binaries underwent common envelope interaction, we find that the released orbital energy is insufficient to unbind the envelope and reproduce the observed properties, implying that additional energy sources are required. In contrast, wider binaries are most consistent with highly non-conservative mass transfer, where at least 70% of the transferred material is lost from the system. The classical prescription for angular momentum loss — mass ejected from the vicinity of the accretor (isotropic re-emission) — produces orbits that are too close, therefore a less efficient scheme is required to reproduce the observations. Our work constitutes the first direct constraints on uncertain binary interactions using the new observations of stripped stars, offering important insights into massive binary evolution. We find that the classical treatment of binary interactions cannot reproduce the observations, and a better understanding of binary evolution is necessary. These results carry significant implications for the formation of rapidly rotating stars, including Be stars, as well as for the later evolution of massive binaries toward stripped-envelope supernovae and gravitational-wave sources.

Inflation or inference? Revisiting the M dwarf radius inflation problem with eclipsing binaries

Authors

Yasmin Davis (1)

(1) University of Birmingham

Abstract

M dwarfs are prime targets in the search for Earth-like exoplanets. However, despite their abundance, they remain comparatively poorly characterised. Their intrinsic faintness and complex features make precise observational constraints on their physical properties challenging, resulting in larger than desired uncertainties in their fundamental stellar parameters. For exoplanet host stars, this limitation is particularly consequential, as the stellar masses and radii inferred from evolutionary models are propagated directly into derived planetary properties. In the low-mass regime, questions remain regarding the validity of these models due to the scarcity of empirically characterised stars, raising concerns about potential systematic biases, most notably the long-debated issue of M-dwarf radius inflation. Low-mass eclipsing binaries (EBLMs) provide a unique opportunity in this regime, enabling direct measurements of stellar masses and radii. By combining space-based photometry with high-resolution ground-based spectroscopy, we exploit the complementary strengths of each method to achieve highly precise and accurate stellar radii measurements. Our homogeneous sample is comprised of over 50 M-dwarf stars ranging from 0.1 to 0.6 Msun, with an average precision of 1.4% on stellar radius. At this unprecedented level of precision, methodological and statistical choices become critical when comparing measured parameters to stellar evolution models. In the past, most work considered uncertainties either in radius, or in mass, but rarely in both. However, with the substantially improved empirical precision we achieve, we needed to develop a new metric to quantify stellar radius inflation accounting for uncertainties in radius and mass, as well as the correlation between them. Using our new inflation metric I will present results from the largest homogeneous study of EBLMs to date. With this approach, we find no evidence for M dwarf radius inflation within the sample. We measure that on average stars between 0.1 and 0.6 Msun have radii 0.3 ± 1.6% larger than models would predict. Our results therefore strongly support the current low-mass stellar evolution models, demonstrating their ability to accurately reproduce the structure of M-dwarf stars, and improving confidence in model-based parameter estimates for single exoplanet host stars.

The radial velocity discovery of BEBOP-5b, a circumbinary planet orbiting a binary containing an evolved primary.

Authors

Aleyna Adamson (1), Amaury Triaud (1), Adam Stevenson (1), The BEBOP Consortium (2)

(1) University of Birmingham
(2)

Abstract

The environment surrounding binary stars is dynamically complicated, making planet formation and survival challenging. Nevertheless, planets are known to exist in binary systems, either orbiting a single star of the binary, circumstellar planets, or orbiting both stars, circumbinary planets. Circumbinary exoplanets have proven the most difficult to detect, with only 19 currently known orbiting main-sequence binaries. To date, just three circumbinary planets have been discovered using radial velocities, all as part of the BEBOP (Binaries Escorted By Orbiting Planets) survey, a project focused on detecting circumbinary planets with radial velocities. In this talk, on behalf of the BEBOP consortium, I will present the fourth such discovery, BEBOP-5b. HARPS radial velocity measurements collected over three years reveal a 0.9 MJup circumbinary planet following a 85 day period. The planet orbits an unusual binary system within the BEBOP sample, consisting of a fairly evolved 1.7 $M_\odot$ primary and a 0.13 $M_\odot$ full convective M-dwarf secondary still on the Main Sequence. Additionally, the radial velocity data contains a long-term drift suggestive of a second, longer-period companion in this system. BEBOP-5b expands the parameter space where circumbinary planets are known to exist and, for the first time, probes the planet population as stars evolve off the Main Sequence. Describing the discovery of this system is also an opportunity to highlight our novel Bayesian approach to quantity a radial-velocity dataset's sensitivity to exoplanets, a method which promises new developments in measuring occurrence rates, featuring fewer arbitrary choices, and able to incorporate candidate planets in a coherent way.

The impact of binary stars on the chemical evolution of galaxies

Authors

Rob Yates (1), David Hendriks (2), Aswin Vijayan (3), Rob Izzard (2), Peter Thomas (3), Payel Das (2)

(1) University of Hertfordshire
(2) University of Surrey
(3) University of Sussex

Abstract

In this talk, I will present results from a new implementation of binary stellar evolution (BSE) using the binary_c code into the galaxy evolution simulation, L-GALAXIES (Yates et al. 2024). The complex evolution of binary stars can significantly affect their lifetimes, nucleosynthesis, and end state, which in turn could have important consequences for overall galaxy evolution. Yet, BSE has not been self-consistently included into cosmological-scale galaxy evolution simulations to study metal and dust evolution, until now.

First, I will explain how we incorporated BSE into L-GALAXIES and will show some comparisons between single and binary-star set-ups. Then, I will discuss the effect of BSE on key galaxy scaling relations. We find that galaxy stellar masses and star-formation rates are not significantly affected by the inclusion of binaries, if the energy deposition by core-collapse supernovae remains relatively unchanged. Similarly, most metal abundances are predominantly impacted by the stellar yields assumed, rather than BSE effects. This demonstrates the viability of including BSE models into galaxy evolution simulations, without the need to drastically recalibrate other physics models. Binaries do noticeably enhance the enrichment of e.g. nitrogen through common envelope ejection, supernovae-Ia, and novae, however. This has interesting consequences for the chemical composition of galaxies at high redshift and in the outer regions of the Milky Way. I will also show how L-GALAXIES + BSE can reproduce the observed dust-to-metal (DTM) and dust-to-gas (DTG) ratios in galaxies back to $z \sim 4$, unlike most other cosmological-scale simulations.

Finally, I will present on-going work to also incorporate BSE into the super-high-resolution hydrodynamical simulation, EDGE. The unrivalled resolution of EDGE (down to $\sim$ 20Msun in gas mass and $\sim$ 3 pc in size) allows it to resolve individual massive stars and supernovae, making it ideal for embedding BSE to study detailed chemical evolution and feedback within SMC- and LMC-like dwarf galaxies.

A match made in heaven: Gaia and APOGEE for binary stellar characterisation

Authors

Rhys Seeburger (1)

(1) Liverpool John Moores University

Abstract

Gaia DR3 has provided a truly unprecedented set of orbit solutions for spatially unresolved binaries, via spectroscopy, astrometry, or photometry. These are complemented excellently by over 80,000 APOGEE spectra. Their higher resolution, high signal-to-noise ratio (S/N), and infrared wavelength coverage can aid in validating and improving binarity measurements from Gaia by identifying smaller RVs and redder secondaries, and measuring flux ratios.

In this work, we use single and binary theoretical spectra to model the APOGEE observations, classifying Gaia binaries as SB1 or SB2, and placing constraints on their H-band flux ratios. We also combine these flux ratios and Gaia orbital solutions to fully solve the component orbits for thousands of systems. Further, we identify a set of interesting SB1 systems with massive, undetected companions. In doing so, we demonstrate the constraining power of even single-epoch high resolution ground based spectroscopy when combined with multi-epoch astrometric solutions for binary identification and parameter estimation.

Magnetic white dwarfs as probes of the double-degenerate merger channel

Authors

Aayush Desai (1), Ilaria Caiazzo (1), Sofia Vasieva (2)

(1) Institute of Science and Technology Austria
(2) Cambridge University

Abstract

Double-degenerate white dwarf mergers are likely endpoints of close binary evolution, yet the structure and evolution of their observable remnants remain incompletely understood. Highly magnetic, rapidly rotating white dwarfs are among the strongest candidates for this channel, connecting binary interaction, magnetic-field generation, and compact-object evolution. In this talk, I will discuss our recent work on periodic magnetic white dwarfs and show how time-domain surveys, especially ZTF and ATLAS, are transforming our ability to identify merger-remnant candidates through rotational variability. Measured periods provide new constraints on the post-merger population and on the relation between rotation, magnetism, and white-dwarf structure. I will briefly highlight ZTF J1901+1458 as an extreme and well-studied example, but the emphasis will be on the emerging population and what it reveals about the merger channel in white dwarfs. Looking ahead, LSST will dramatically expand this sample, enabling population-level tests of how compact binaries produce massive, magnetic, and rapidly rotating remnants. Magnetic white dwarfs, therefore, provide a powerful observational link between binary-star evolution and the late-time outcomes of binary star systems.

An SDSS-V view on the multiplicity of massive stars

Authors
Jaime Villaseñor (1)

(1) Max Planck Institute for Astronomy

Abstract
SDSS-V is delivering an unprecedented spectroscopic census of massive stars across the Milky Way and nearby environments. For the first time, a survey is providing a sample large enough to characterise massive-star multiplicity on a truly population scale. Because the evolution of massive stars is fundamentally shaped by binary interactions, progress requires not only very large samples, but also a homogeneous framework to connect binary diagnostics with the underlying stellar properties. SDSS-V is uniquely positioned to provide exactly that.

In this talk I will present a new analysis framework for the SDSS-V massive-star sample, comprising nearly 40,000 stars observed with BOSS, with a particular focus on binary identification and characterisation. I will present new binary diagnostics and our strategy to measure the binary fraction as a function of evolutionary state and environment, directly linking the physical parameters (effective temperatures, surface gravities, and projected rotational velocities) to the multiplicity analysis. This makes it possible to place the binary population in its proper physical context and to quantify how multiplicity depends on stellar properties across the survey.

Together, these results provide the first homogeneous characterisation of massive-star multiplicity achieved by any spectroscopic survey at this scale. This work lays the foundation for a wide range of high-impact science, from the population demographics of massive binaries to the identification of stripped stars, interacting systems, and candidate compact-object companions. I will present the first population-level results from this effort together with the associated catalogue products.

Revising analytic equations of stellar evolution to include massive stars and alpha-enhancement: Implications for binary population synthesis

Authors

Conor Byrne (1), Elizabeth Stanway (1), Jan Eldridge (2)

(1) University of Warwick
(2) University of Auckland

Abstract

Binary population synthesis frequently relies on analytic prescriptions to approximate the evolution of both stellar components, as detailed modelling of entire stellar populations can be computationally prohibitive. However, the most widely used prescriptions are based on stellar models computed nearly 30 years ago, are limited to masses below 50 solar masses, and assume Solar-scaled compositions. This limits their reliability when extrapolated to tackle modern problems, such as binary black hole populations and stellar populations in the distant Universe.

I will present a new set of analytic formulae calibrated against a dense grid of detailed single-star models from the Binary Population and Spectral Synthesis (BPASS) framework. These models incorporate updated opacity tables, nuclear reaction rates, and variable composition, including alpha-enhancement. The resulting prescriptions reproduce Main-Sequence luminosities, radii, and lifetimes with RMS errors below 0.1 dex, while extending the valid mass and composition range.

I will demonstrate how adopting these updated prescriptions alters the outcome of rapid binary population synthesis, including changes to the end states of binary evolution and predicted compact object populations at the 10 per cent level. These results highlight the sensitivity of binary evolution predictions to the underlying stellar physics and underscore the need to revise standard analytic treatments in the era of large-scale surveys like LSST and high-redshift observations with space telescopes such as JWST.

Posters

Modelling X-ray Binary Populations with BPASS

Authors

John Bray (1)

(1) University of Auckland

Abstract

Over the past decade there have been a number of studies attempting to understand how the X-ray luminosity of stellar populations might be used to understand star formation rates and histories. (Lehmer 2017, 2019, 2020). In addition, some researchers suggest recent observations of excess nebular He(II) emission seen in the rest frame ultraviolet spectra of high-redshift galaxies may be explained by X-ray emission from XRBs (Schaerer 2019), while others (Senchyna 2020), suggest XRBs cannot account for all of the line flux observed.

In this presentation we summarise how we combine the detailed BPASS stellar models with standard accretion disc models to calculate the spectra, HMXB numbers and time evolution of the X-ray flux for a 10^6 M☉ starburst galaxy at various metallicities. We compare our XRB numbers with those obtained by Antoniou (2021) for the SMC and the total X-ray flux with Lehmer (2017) for M51.

Exploring the circumbinary desert with Gaia, TESS, and PLATO

Authors

Frédéric Marcadon (1), Ayush Moharana (2), Tilak Pawar (3), Ganesh Pawar (1), Krzysztof Hełminiak (1)

(1) Nicolaus Copernicus Astronomical Center
(2) Keele University
(3) Villanova University

Abstract

While the existence of a brown dwarf (BD) desert is well established, there is another desert, hereafter referred to as the circumbinary desert, that deserves to be further investigated. This circumbinary desert is characterized by a dearth of short-period stellar and substellar companions around eclipsing binaries (EBs).
On the one hand, EBs orbited by a close (Pout < 1000 d) stellar companion are rare among the entire population of hierarchical triple stellar systems. Such systems, referred to as compact hierarchical triples, or CHTs, are thought to form differently than wider triple systems, most likely through a sequential disk fragmentation mechanism. On the other hand, there is a clear deficit of circumbinary BDs with orbital periods less than 1000 d, which might indicate different formation mechanisms for close-orbiting BDs and isolated ones. Indeed, it is commonly accepted that BDs in close orbit around main-sequence single stars can be divided into two populations distinguishable by their physical and orbital properties. One of them consists of high-mass BDs formed like stars through the fragmentation of molecular clouds, while the other consists of low-mass BDs that are thought to be formed by disk instability in the same manner as planets.
In order to examine the population statistics of the circumbinary desert, it is necessary to increase the number of confirmed circumbinary systems. Recent studies have demonstrated the feasibility of detecting short-period circumbinary companions with masses as low as those of BDs in the Transiting Exoplanet Survey Satellite (TESS) full frame images using the eclipse timing variation (ETV) method. However, the detection of the lowest-mass, shortest-period circumbinary candidates will require a dedicated photometric survey based on high-precision and high-cadence data from the future ESA PLAnetary Transits and Oscillations of stars (PLATO) space mission, which is scheduled for launch in January 2027. Alternatively, it is possible to identify new CHT candidates by taking advantage of the non-single-stars catalog from Data Release 3 of the ESA Gaia space mission. Thus, the present project aims to contribute to our understanding of the circumbinary desert in the era of Gaia, TESS, and PLATO.
The purpose of this project is twofold. First, we aim to assess the reality of the circumbinary desert by performing a systematic ETV search for short-period tertiary companions among a sample of ~2800 EBs observed by TESS during Cycle 7 (October 2024-September 2025) as part of our Guest Investigator program G07071. Second, we plan to reanalyze a sample of ~140 compact triple candidates identified in the literature using TESS short-cadence data. The newly discovered and the reanalyzed systems will then serve as benchmark objects to test and validate our ETV extraction procedure, with the future goal of applying it to the whole sample of EBs that will be observed by PLATO.

Eclipsing Binaries from the Next Generation Transit Survey

Authors

Toby Rodel (1), Sarah Casewell (2)

(1) Queen's University Belfast
(2) University of Leicester

Abstract

The Next Generation Transit Survey (NGTS) is a world class facility for photometry located in Paranal, Chile. The flexibility of NGTS alongside its red optical capability and fast 13s cadence have allowed us to make numerous contributions to the field of eclipsing binaries, especially for systems containing one or more late M dwarf or brown dwarf companions. Here we will provide an overview of the eclipsing binary science being done within the NGTS consortium. This includes two rare spectroscopic double lined M+M binaries, as well as some of the longest period late M and brown dwarf companions ever discovered. We have also recently begun a programme to search for double white dwarf binaries in our dataset. NGTS is open to requests for observations for any science case and our streamlined proposal system makes it easy to request observations for your own targets.

Characterisation of EBLM benchmark stars and their M-dwarf companions

Authors

Axel Hahlin (1), Pierre Maxted (1), Natasha Adshead (1), Claudia C. Aguilera-Gómez (2), Ivanna Hernández (2)

(1) Keele University
(2) Pontificia Universidad Católica de Chile

Abstract

We have characterised a set of 5 low-mass eclipsing binaries containing FG primary components and M-dwarf secondaries. The goal of this has been twofold. Firstly, the aim has been to provide a set of Sun-like benchmark stars that can be used as verification of pipelines used in large-scale surveys. Secondly, we have been able to provide accurate parameters of the secondary components, this provides a set of well-characterised M-dwarfs that could be used to improve our understanding of the structure and evolution of low-mass stars.
To achieve this, we have utilised TESS lightcurves for eclipses and high-resolution spectroscopy from both HARPS and NIRPS at the ESO 3.6m telescope to obtain radial velocities and chemical compositions. While the secondary component is not visible in individual spectra, its contribution is sufficiently high so that we are able to use cross-correlation to extract dynamical properties of the secondary and derive precise fundamental parameters for both components. Using the obtained parameters we also produce high S/R spectra of the primary, where the contribution of the secondary component has been removed. This allows us to estimate the effect the secondary component have on the chemical composition measurements of the primary.
Another aspect of these targets is that their magnitudes is in the range (9-11). While fainter than typical benchmark stars, this places them at similar magnitudes that are typically targeted by large-scale spectroscopic surveys. For this reason, they will be observable by future missions and used as a self-consistent verification of the performance of pipelines for obtaining stellar parameters.

Mapping the Mass Discrepancy in Eclipsing Binaries

Authors

Ema Šipková (1), Nadya Serebriakova (1), Andrew Tkachenko (1)

(1) KU Leuven, Institute of Astronomy

Abstract

The physical state of a star is primarily determined by its initial mass and chemical composition, while other factors (e.g. rotation, magnetic fields, companion) play a secondary role. Precise stellar masses are essential for constraining stellar structure and evolution (SSE), particularly for rapidly evolving stars more massive than ~1.2 solar masses (i.e. OBAF-type stars). Model-dependent mass estimates (spectroscopic and evolutionary masses) are limited by observational uncertainties and by the simplified one-dimensional treatment of stellar interiors in SSE models. Their reliability depends on both the quality of observational constraints and the accuracy of interior and evolutionary modelling. In contrast, eclipsing double-lined binaries yield model-independent dynamical masses from orbital dynamics. Systematic differences between dynamical and model-dependent masses constitute the long-standing mass discrepancy problem, observed in both single and binary stars. Proposed explanations include binary interaction, rotational mixing, and convective overshooting, yet no single mechanism explains all cases. Our research investigates the mass discrepancy over a large sample of eclipsing binary systems with different configurations, enabling an empirical mapping of this effect over a broad parameter space. The goal is to identify the key parameters correlated with the discrepancy and to formulate prescriptions for improving stellar atmosphere and SSE models. This will be accomplished through detailed modelling of selected benchmark systems, targeting mass determinations with precision better than 5%.

The impact of modelling approaches and data precision on massive pulsating eclipsing binaries

Authors

Logan Dennis (1), Dominic Bowman (2), Michael Abdul-Masih (3)

(1) Newcastle University
(2) Newcastle University, KU Leuven
(3) Instituto de Astrofísica de Canarias, Universidad de La Laguna

Abstract

Understanding the structure and evolution of massive stars is key for understanding a myriad of concepts in physics, including galactic evolution, black holes and neutron stars. Most massive stars exist in multiple systems with eclipsing binaries being some of the most powerful laboratories for testing stellar physics.
This is because eclipsing binaries allow the determination of model independent masses and radii.
A significant amount of these massive eclipsing binaries also pulsate.
Asteroseismology, the study of pulsations, probes stellar structure and when combined with binarity provides ultra-precise constraints on interior physics such as rotation and mixing.
However, there is currently a variety of different approaches to binary modelling of massive pulsating eclipsing binaries.
Differences arise both in the binary-modelling techniques such as geometrical assumptions imposed by different modelling codes and in the photometric and spectroscopic data-processing pipelines used.
In this presentation we show the impact of different binary modelling approaches and different precision data using the binary modelling code PHOEBE.
We take two different approaches for a sample of pulsating massive eclipsing binaries and compare conducting iterative pre-whitening to identify pulsation mode frequencies in time-series space photometry before and after the binary modelling.
We compare the results obtained from different combinations of TESS light curves extracted using different extraction methodologies together with archival and new radial velocity data.
This allows for a direct comparison and quantification of the impact of the different modelling approaches and data on the masses and radii.
We test the impact that the geometrical assumptions imposed by different modelling codes have on the derived best fit parameters.
Understanding the impacts of different approaches is important as the dynamical masses and radii found from binary modelling are needed to put ultra-precise constraints on stellar structure and evolution models in binary asteroseismology.
By using the most up-to-date data and advanced processing techniques, we evaluate whether different modelling approaches can converge on a consistent solution under optimal conditions.
We conclude that understanding which approach is better is vital to test the accuracy of stellar structure models, and using Roche geometry affects the radii extracted from our sample.

About the stability of circumbinary planets: binary properties and migration scenarios

Authors

Romain Grane (1), Nicolás Cuello (1), Mario Sucerquia (1), Emmanuel Gianuzzi (2), Carolina Charalambous (3), Milenne Ávila-Bravo (3), Amaury H. M. J. Triaud (4)

(1) Univ. Grenoble Alpes, CNRS, IPAG, Grenoble, France
(2) Instituto de Astronomía Teórica y Experimental (IATE), UNC-CONICET, Córdoba, Argentina
(3) Instituto de Astrofísica, Pontificia Universidad Católica de Chile, Santiago, Chile
(4) School of Physics & Astronomy, University of Birmingham, Birmingham, UK

Abstract

Since their first detections in the 2010s, circumbinary planets have continued to challenge our understanding of planet formation and dynamics. Fewer than twenty are currently confirmed around main-sequence binaries, even though multi-star systems are very common [1]. Most known systems lie close to the dynamical stability limit of their host binaries [2], and only a handful are part of multi-planet systems. While observational biases contribute to this trend, they cannot fully account for the scarcity and inward concentration of circumbinary planets [3], suggesting that dynamical processes play a major role in shaping their long-term survival.

We investigate the dynamical stability of circumbinary multi-planet systems, focusing on configurations with two Super-Earths embedded in a circumbinary protoplanetary disk. Using N-body simulations coupled with a migration prescription, we explore how the binary mass ratio qB and eccentricity eB affect planetary stability. We also consider two migration pathways: planets migrating sequentially, and planets migrating together and captured into a planet–planet mean-motion resonance.

Based on more than 1,000 simulations, our results indicate that inward migration can, in some cases, be halted through resonance capture with the binary. In contrast to previous purely N-body studies (e.g., [4]; [5]), such configurations appear to remain stable over long timescales, suggesting the existence of an additional stable location beyond the disk's inner edge. We further find that the binary parameters qB and eB play a key role in shaping the stability landscape of multi-planet systems. Within the explored parameter space, some regions support long-term stability, whereas others appear highly unstable. These stability regions may be highly sensitive to the migration timescales (i.e., to disk properties and planetary masses). Finally, our simulations suggest that systems in which two planets enter resonance while migrating together are more likely to form stable multi-planet configurations, particularly around highly eccentric binaries.

These results allow us to better identify stable configurations of circumbinary planetary systems for a broad variety of binaries. This is key to select and monitor the most favorable targets for ongoing and future observational campaigns such as BEBOP, Gaia and PLATO.

References:
[1]: Duquennoy, A. & Mayor, M. 1991, A&A, 248, 485.
[2]: Welsh, W. F., Orosz, J. A., Carter, J. A., & Fabrycky, D. C. 2014, in IAU Symposium, Vol. 293, Formation, Detection, and Characterization of Extrasolar Habitable Planets, ed. N. Haghighipour, 125–132.
[3]: Martin, D. V. & Triaud, A. H. M. J. 2014, A&A, 570, A91.

[4]: Martin, D. V. & Fitzmaurice, E. 2022, MNRAS, 512, 602.
[5]: Gianuzzi, E., Giuppone, C., & Cuello, N. 2023, A&A, 669, A123.

Exploring the Uncertainties in Binary Stellar Population Synthesis modelling

Authors

Elizabeth Stanway (1)

(1) Warwick

Abstract

The stellar population synthesis of binary stars require a range of assumptions regarding their evolution, their spectra and their interactions. Here we consider the current state of the art of binary stellar population modelling and look forward at some of the challenges ahead.

The surprising binary populations of massive star clusters

Authors
Sebastian Kamann (1)

(1) Liverpool John Moores University

Abstract
In my talk, I will highlight the results from our MUSE survey of binary stars in massive star clusters. Integral-field spectroscopy gives us the opportunity to monitor thousands of stars in the crowded centres of both young massive clusters and ancient globular clusters for line-of-sight velocity variations. Via statistical methods such as nested sampling, we are able to constrain the orbital periods of the detected binaries and infer their companion masses. Our survey has resulted in the detection of several dormant black hole candidates and revealed a dearth of short-period binaries in various clusters. The latter comes as a surprise because the dense cluster environments are expected to favour the formation of hard binaries via few-body encounters, whereas soft binaries with wide orbits should be preferentially destroyed. I will discuss the implications of our results for our understanding of the dynamical evolution of stars clusters and the binaries within. I will also highlight the observational and theoretical uncertainties currently limiting our understanding of whether massive star clusters are "gravitational wave factories" that contribute substantially to the observed frequency of binary black hole mergers.

Testing tidal theory with the period-eccentricity distribution

Authors

Alexander (1), Caroline Terquem (2)

(1) Boone
(2) University of Oxford

Abstract

While tides are crucial for understanding dynamical evolution of binary systems, a clear picture of the dominant mechanism for tidal dissipation has remained elusive. Past attempts to constrain the efficiency of tidal dissipation have focused on the "circularisation period"; however this discards much of the information in the full period-eccentricity distribution. We forward-model the period-eccentricity distribution by evolving binary populations under both dynamical and equilibrium tidal prescriptions, incorporating self-consistent rotation and stellar structure. We then compare our simulated distributions to heterogeneous observational data to distinguish between tidal prescriptions.

Better understanding EBLMs with longer orbital periods.

Authors
Samuel Carlier (1)

(1) University of Leicester

Abstract
Despite being the most numerous stars in the Galaxy, our understanding of M dwarfs is still lacking, especially when comparing their radii to evolutionary models for a given mass. Potential reasons for this discrepancy include magnetic activity, metallicity, rotation and star spots. M dwarfs in binaries provide a direct method with which to measure the radii of low mass M dwarfs, stars which are often used as targets for transiting exoplanet searches.
This project aims to add to the existing known EBLMs, prioritising M+M pairs with longer orbital periods, using transiting candidates flagged in TESS data for NGTS follow-up and RVs from CORALIE to produce constrained parameters through SED fitting. This project is part of the NGTS consortium.

Predictions of the detectability and confirmability of self-lensing binaries in future surveys

Authors

Adam McMaster (1), Matthew Middleton (1)

(1) University of Southampton

Abstract

Self-lensing is a phenomenon wherein a lens in an edge-on, binary orbit with a star creates a microlensing magnification once per orbit. This phenomenon is only possible when the lens is a compact object, and to date a handful of self-lensing binaries containing white dwarfs have been detected in data from Kepler. We are conducting a search for such binaries in the hopes of finding examples of self-lensing systems containing neutron stars and black holes. In particular this is motivated by the fact that self-lensing is one of the few ways to potentially detect non-interacting black holes in binaries. The primary way to distinguish between microlensing and self-lensing is by the periodic nature of the phenomenon. However, the largest magnifications are produced by the systems with the longest orbital periods. Orbital periods possibly range from days to centuries, making photometric detection and RV followup challenging. By simulating photometric observations of self-lensing binaries we place limits on the physical properties of systems which could be detected, and which of those could be successfully followed up with RV measurements to determine the lens mass and orbital configuration.