UNIVERSITY OF SURREY

PULSATIONS IN INTERMEDIATE-MASS, MASSIVE AND/OR MULTIPLE STARS

ONLINE EVENT

WORKSHOP PROGRAMME

18 – 22 JANUARY 2021

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INTRODUCTION

Most stellar systems are binaries in which stars form as twins. Having a companion greatly impacts their evolution. Tides deform and spin up stars, and excite oscillations, while cataclysmic events like mass transfer, common envelopes, mergers and explosions can create exotic stellar objects that challenge stellar evolution theory.

Over the last few decades, asteroseismology has become a major source of information about stellar interiors. The Corot, Kepler and TESS space-missions measured thousands of stellar lightcurves. Their analysis yields stellar masses and radii with unprecedented accuracy, but mostly in single or non-interacting stars. Stars in close binaries were, and are, neglected in stellar-oscillation studies because of their far more complicated evolutionary paths. Their study requires dedicated techniques that link oscillations to binary-star interaction physics, and similarly complex methods to match models with observations. In particular, correct interpretations of oscillation frequencies in binaries will drive the development of next-generation stellar models including more precise treatments of internal mixing and multidimensional effects.

This breakthrough international workshop will pioneer the potential of asteroseismology in the analysis of binary stars. It will connect international experts in these fields at all stages of their careers, to forge new approaches and techniques that build on the wealth of data delivered by 21st-century astronomical missions like Corot, Kepler, TESS and BRITE, and advanced stellar evolution modelling.

Workshop Chair:
Dr Giovanni Mirouh, University of Surrey

Organising committee:
Dr Robert Izzard, University of Surrey
Mr David Hendriks, University of Surrey
Dr Andrea Miglio, University of Birmingham

Administrative support:
Ms Vicki Blamey, Ms Mirela Dumic and Ms Joanna Moore (University of Surrey)

PROGRAMME

DAY 1 – MONDAY 18TH JANUARY

(GMT)	
09.00 – 09.30	Introduction to the first PIMMS workshop – **Dr Giovanni Mirouh**
09.30 – 10.30	Seismology of solar-type pulsators: outstanding observational results – **Dr Charlotte Gehan**
10.30 – 11.30	Seismology of coherent pulsators: what can we learn from pulsations and binarity in early-type stars? – **Dr Dominic Bowman**
11.30 – 12.30	Break
12.30 – 13.30	Interacting stars and asteroseismology – **Dr Robert Izzard**
13.30 – 14.00	Experimental advances in explosive nuclear astrophysics – **Dr Gavin Lotay**
14.00 – 15.00	Galactic archaeology: (some) challenges posed by binary stars – **Dr Andrea Miglio**
15.00 – 15.30	Break
15.30 – 17.00	Collaborative time for discussion

DAY 2 – TUESDAY 19TH JANUARY

(GMT)	
09.00 – 09.30	Coffee/tea time and discussion
09.30 – 10.30	Seismology of rotating stars – **Dr Giovanni Mirouh**
10.30 – 11.00	Long-period Pulsations of Intermediate-Mass Stars from Radial Velocity Planet Surveys – **Ms Vera Wolthoff**
11.00 – 11.30	Binarity among Type II Cepheids – **Dr Monika Jurković**
11.30 – 12.30	Break
12.30 – 13.30	Binary mass transfer – **Dr Onno Pols**
13.30 – 14.00	Mass transfer and accretion disks – **Mr David Hendriks**
14.00 – 14.30	The post-mass transfer binary system KIC 10661783 – **Mr Amadeusz Miszuda**
14.30 – 15.30	Break
15.30 – 17.00	Collaborative time for discussion

PROGRAMME

DAY 3 – WEDNESDAY 20TH JANUARY

(GMT)	
09.00 – 09.30	Coffee/tea time and discussion
09.30 – 10.30	Inversions in asteroseismology: dissecting the internal structure of stars – **Dr Gaël Buldgen**
10.30 – 11.30	High precision measurements of eclipsing binary stars – **Dr Pierre Maxted**
11.30 – 12.30	Break
12.30 – 13.00	Mapping pulsations in eclipsing binaries – **Dr Barna Imre Bíró**
13.00 – 13.30	A stochastic sampling method for the analysis of eclipsed pulsations – **Mr András Bókon**
13.30 – 14.30	The effects of mixing on accreted material – **Dr Richard Stancliffe**
14.30 – 15.00	Binary star with a pulsating component – **Dr Przemysław Walczak**
15.00 – 15.30	Break
15.30 – 17.00	Collaborative time for discussion

DAY 4 – THURSDAY 21ST JANUARY

(GMT)	
09.00 – 09.30	Coffee/tea time and discussion
09.30 – 10.30	Search for quiet stellar-mass black holes lurking in binary systems by asteroseismology from space – **Prof Hiromoto Shibahashi**
10.30 – 11.30	Tidal forcing and dissipation in binary stars – **Prof Gordon Ogilvie**
11.30 – 12.30	Break
12.30 – 13.00	An eccentric binary system TYC4038-693-1 with a pulsating component – **Dr Erika Pakštienė**
13.00 – 14.00	Tidal asteroseismology: an observational perspective – **Dr Zhao Guo**
14.00 – 14.30	Epsilon Cygni: a possible case of a very extreme heartbeat system – **Mr Paul Heeren**
14.30 – 15.00	Single-sided pulsators – **Prof Gerald Handler**
15.00 – 15.30	Break
15.30 – 17.00	Collaborative time for discussion

PROGRAMME

DAY 5 – FRIDAY 22ND JANUARY

(GMT)	
9.30 – 10.30	Machine learning in stellar physics – **Dr Gregor Traven**
10.30 – 11.00	Augmented Sliced Wasserstein Distances – **Dr Yunpeng Li**
11.00 – 11.30	Pulsations in faint blue stars – **Dr Conor Byrne**
11.30 – 12.30	BREAK
12.30 – 13.30	Non-radial pulsations in Hot Subdwarf B Stars – **Dr Holly Preece**
13.30 – 14.30	Neutron stars – **Dr Arnau Rios-Huguet**
14.30 – 15.00	Concluding remarks – **Prof Simon Jeffery**

ABSTRACTS AND PARTICIPANTS

MONDAY 18TH JANUARY

Seismology of solar-type pulsators: outstanding observational results

Dr Charlotte Gehan, Instituto de Astrofísica e Ciências do Espaço, Universidade do Porto (Portugal)

The last decade has witnessed the advent of ultra-high photometry space missions, with CoRoT and Kepler giving birth to ensemble asteroseismology and providing outstanding results for thousands of pulsating stars. The harvest continues with the ongoing TESS space mission and the future PLATO mission expected to be launched by 2026.

This review will focus on solar-type pulsators, with a particular emphasis on evolved oscillating stars that offer the opportunity to study the physical conditions governing stellar cores through the mixed modes in their oscillation spectrum. I will review the theory behind solar-type pulsations and focus on elements of stellar structure as solar-type pulsators go through different evolutionary stages, before focusing on some of the major observational results obtained so far.

Seismology of coherent pulsators: what can we learn from pulsations and binarity in early-type stars?

Dr Dominic Bowman, KU Leuven (Belgium)

Stars which possess a convective core during the main sequence play a critical role in stellar evolution theory. In particular, massive stars are important metal factories which provide energy and chemical feedback to their surroundings. However, current stellar evolution models contain large theoretical uncertainties for these early-type stars. The uncertainties associated with interior rotation, mixing and angular momentum transport propagate throughout a star's evolution making it difficult to accurately determine masses and ages, with the situation becoming more complex in the case of binary systems. However, the high incidence rates of pulsation and binarity for early-type stars allow us to break model degeneracies, uniquely probe stellar interiors, and calibrate the unknown physics within stellar evolution models. In this review, I discuss the advances in our understanding of early-type stars by means of asteroseismology and binarity. Asteroseismic modelling provides important constraints on ages, core masses, interior mixing,

Continued

rotation and angular momentum transport for stars pulsating in coherent modes. Furthermore, space photometry of eclipsing binary systems containing a pulsating star facilitates binary asteroseismology, with such systems yielding the most accurate masses, radii and ages. Thanks to the recent Kepler and TESS space telescopes, a wide range of diverse variability has been discovered in early-type stars, which can be exploited to constrain stellar structure and evolution models for some of most massive and short-lived stars in the Universe.

Interacting stars and asteroseismology
Dr Robert Izzard, University of Surrey (UK)
Models of stellar populations including only single stars are yesterday's news: we now know that most stars more massive than the Sun are in multiple systems. Many of these are binaries or in higher-order multiples which are hierarchical so contain gravitationally bound effectively-single stars and binaries. I will review how these systems evolve and how their stars interact, including mass and angular momentum transfer, and stellar merging, with a focus on how interaction alters their evolution and hence their asteroseismological properties.

Experimental advances in explosive nuclear astrophysics
Dr Gavin Lotay, University of Surrey (UK)
Classical novae are among the most frequent and violent stellar explosions to occur in our Galaxy. As such, they play a key role in determining its chemical evolution. Recently, remarkable advances in astronomy and meteoritics have produced a wealth of observational data on these cataclysmic astronomical events, giving us unprecedented insight into their properties. However, a detailed understanding of this latest observational data is severely hindered by large uncertainties in the underlying nuclear physics processes, involving unstable nuclei, that drive such stellar scenarios.

Modern state-of-the-art accelerator facilities provide the means to resolve this issue, through their ability to recreate the conditions that occur in explosive stellar phenomena in terrestrial laboratories. In particular, it is now possible to obtain key experimental information on the rates of astrophysical processes that govern both the rate of energy release and pathway of nucleosynthesis in classical novae. In this talk, recent experimental studies of relevance for classical novae will be discussed.

Galactic archaeology: (some) challenges posed by binary stars
Dr Andrea Miglio,
University of Birmingham (UK)
In this review I will first touch upon some of the recent advances in using large samples of stars with asteroseismic constraints to reconstruct the assembly history and evolution of the Milky Way. I will then discuss examples on how binary stars pose a serious threat to these endeavours, and how one can identify stars that had undergone interaction with a companion by combining asteroseismic, astrometric, and spectroscopic data.

TUESDAY 19TH JANUARY

Seismology of rotating stars

Dr Giovanni M. Mirouh,
University of Surrey (UK)

Rotation is ubiquitous in stars, it affects all stages of stellar evolution and associated oscillations. While slowly-rotating solar-like stars are well described by perturbative treatments, rapid rotation is a notorious source of complexity in so-called classical pulsators. In this review, I will briefly summarize the origin and impact of stellar rotation, and present recent works that crucially developed new approaches to describe the internal rotation of a growing number of stars across the Hertzsprung-Russell diagram. I will focus on rapidly-rotating main-sequence stars, in which theory and observations are finally converging thanks to the detection of regular patterns predicted by the models. All these exciting results offer ways of exploiting the unprecedented wealth of data provided by the Corot, Kepler and TESS space missions, and light the way to great future advances with the upcoming PLATO mission.

Long-period Pulsations of Intermediate-Mass Stars from Radial Velocity Planet Surveys

MsVera Wolthoff, ZAH-LSW
University of Heidelberg (Germany)

Intermediate-mass (IM) stars (M>1.5Msun) are difficult targets for radial velocity (RV) surveys while they are on the main sequence, due to their hot atmospheres and fast rotation. Therefore, the planet search has mainly focused on evolved IM stars with most planet hosts being red giants (~100 known today). However, the long-period behavior of these stars is not well understood causing several planet candidates to be refuted after additional observations were made (e.g. Hatzes et al. 2018, Delgado Mena et al. 2018, Reichert et al. 2019). So called oscillatory convective modes (OCM), which have originally been proposed (Saio et al. 2015) to explain the long secondary periods of OGLE III giants with log(L/L_sun)>3 (and typical periods of several hundred days), were suggested as a possible origin for the signals in question. Since RVs are more sensitive to low-amplitude pulsations (and in particular to non-radial ones) than photometry, OCMs could potentially be picked up in RV planet searches for luminosities below the threshold. We present data from our 11 year RV Lick giant star survey and compare it to the expected period-luminosity relations for OCMs. Furthermore, we look at the prominent scarcity of Hot and Warm Jupiters (periods<90days) around IM stars and show that the combined effects of simple stellar equilibrium tides and Reimers' mass loss on the planetary orbits cannot reconcile the differences between main sequence and giant stage planet populations for stars with M>2Msun (while for lower-mass giants, these planets are efficiently removed).

Binarity among Type II Cepheids

Dr Monika Jurković,
Astronomical Observatory Belgrade (Serbia)

Type II Cepheids (T2Cs) were known to be radially pulsating variable stars, with periods from 1 to 150 days. This picture seems to be changing. T2Cs pulsating in a first overtone, and in the fundamental mode and first overtone simultaneously were discovered in the Magellanic Clouds (MCs) from the Optical Gravitational Lensing Experiment (OGLE) IV catalog. Type II Cepheids are divided into subgroups according to their pulsation period: BL Herculis (BLH), 1-4 days, W Virginis (WVir), 5-20 days, RV Tauri (RVT), 20-150 days. Among them binary systems are found in the sub-types: peculiar W Virginis (pWVir) stars (80% are in a binary systems) and RV Tauri stars. The pWVir systems OGLE-LMC-T2CEP-098 and OGLE-LMC-T2CEP-211 are two of such binary systems from the Large Magellanic Cloud (LMC) that were studied in detail. The mass of the T2C in OGLE-LMC-T2CEP-098 was found to be 1.51± Msun, while for the OGLE-LMC-T2CEP-211 the current mass of the pulsating star is 0.64±0.02 Msun. This would suggest that in binary systems the pulsating stars light curve resembles T2Cs, despite them having larger masses than the single T2Cs (which is ~0.5-0.6 Msun). The RV Tauri sub-type of T2Cs show alternating minima and maxima in their light curves with long periods of variation. This makes their observation quite time consuming and challenging. From the studied RVT stars in the Milky Way it seems that those showing a disc like distribution of dust seen in the Spectral Energy Distribution are in a binary systems. Another method to find these binaries is to use the light-time travel effect (LITE). This was carried out for one third of T2Cs in the MCs in the OGLE-III catalog.

Binary mass transfer

Dr Onno Pols,
Radboud University Nijmegen (Netherlands)

The evolution of binary systems deviates from that of single stars primarily owing to the possibility of mass transfer, giving rise to a wide range of phenomena including blue stragglers, barium stars, X-ray binaries, Type Ia supernovae and gravitational-wave sources. Mass transfer can occur by means of two main processes, Roche-lobe overflow and stellar-wind mass transfer. In this talk I will give an overview of our current understanding of these processes: their stability, efficiency, and consequences for the evolution of the binary orbit. Special emphasis will be on mass transfer from red giant and AGB donors, which is expected to result in binaries with some of the least understood observed properties: intermediate-size orbits (of several AU), peculiar abundances and substantial eccentricities.

Disky business: disk mass transfer in Algol systems

Mr David Hendriks, University of Surrey (UK)

It has become clear that a significant fraction of stars has one or more companions. Stars in a binary, or higher order, systems often interact by transferring mass, drastically altering their evolution compared to single stars. The transfer of material from one star to the other affects the mass ratio, orbital evolution and can even lead to the stars merging together. This process is not always conservative, and in many systems we expect some mass to have been lost in this process. The transferred material does not always directly hit the accreting object, in certain cases it forms an accretion disk. Accretion onto a star can affect the pulsational properties and the period of the pulsations of the accretion star. It is unclear whether disk accretion has a distinctly different effect on the pulsations than direct accretion. In accretion disks viscous processes within the disk transport the angular momentum outward and tidal interactions with the edge of the disk are expected to transport the excess angular momentum back into the binary orbit. Material at the outer edge potentially carries a very large specific angular momentum, and would some of that material be lost from the disk before being able to return its angular momentum to the orbit, it could alter the orbital evolution, as well as estimates for the mass transfer efficiency. In this talk I will show several results of synthetic populations of Algol systems, and properties of disks in these systems. I will compare different assumptions of mass loss from these disks and show the effect that has on their further evolution.

The post-mass transfer binary system KIC 10661783

Mr Amadeusz Miszuda
(with Dr Wojciech Szewczuk, Dr Jadwiga Daszyńska-Daszkiewicz)
University of Wroclaw (Poland)

KIC 10661783 is a detached post-Algol binary system with a short orbital period. This is a double-lined eclipsing binary and the stellar parameters of its components are determined with an accuracy below 1.5%. The main component is a delta Scuti pulsating star. Up to now, 55 independent pulsation frequencies were identified in the 28-day Kepler light curve. We present results obtained from all available Kepler data which include a 769-day time interval. The Fourier analysis of the whole light curve, corrected for the binary effects, reveals 750 frequency peaks and those with the highest amplitudes are concentrated in the range of 20 - 30 c/d. In addition, we found small-amplitude signals in the low-frequency range that can be manifestation of gravity-mode pulsations. Asteroseismic modelling with precisely determined fundamental parameters allows to obtain more reliable constraints on other parameters of the model and theory. In particular, our goal is to find corrections to the mean opacity profile to account for the whole frequency range observed in the delta Scuti star.

WEDNESDAY 20TH JANUARY

Inversions in asteroseismology: dissecting the internal structure of stars

Dr Gaël Buldgen,
Observatoire de Genève (Switzerland)

Inversion techniques are standard tools in geophysics and helioseismology, leading to tremendous successes. Meanwhile, their use in asteroseismology, although already foreseen in 1990s, was for long proscribed as a result of the limited amount of data. The scenery changed dramatically with the CoRoT and Kepler missions, which allowed the widespread use of sophisticated inference techniques in asteroseismic investigations. In the current era of space-based photometry missions such as TESS and the future PLATO mission, these techniques are slowly but surely becoming more routinely used, paving the way for more in-depth testing of stellar models.

I will review the current data, methodologies and physical information that can be extracted from asteroseismic data as well as discussing a interesting targets where inversion techniques played or may play a key role in testing the theory of stellar structure and evolution.

High precision measurements of eclipsing binary stars

Dr Pierre Maxted, Keele University (UK)

The volume and quality of data available for stellar populations and exoplanet systems is now so good that the main obstacle to answering the big questions in exoplanet and galactic astrophysics is often the missing physics in stellar models used to interpret these data. These surveys also provide the tools that are needed to make very accurate and precise measurements of stars in eclipsing binary systems. In this talk I will review the theory behind making accurate mass and radius measurements for stars in eclipsing binary systems, and discuss how the analysis of carefully-selected binary systems with state-of-the-art techniques can be used to calibrate the next generation of stellar models.

Mapping pulsations in eclipsing binaries

Dr Barna Imre Bíró, Baja Observatory of the University of Szeged (Hungary)

We explore the potential of eclipses in binary systems to provide information on pulsations of their components. In particular, we are interested in developing methods of analysis that use their modulating and surface sampling effect to infer the surface patterns of the pulsations on the components of eclipsing binaries. Ultimately this could lead to a direct identification of the modes, and since the eclipses are a purely geometric phenomenon, the whole procedure can stay largely independent of asteroseismologic models, with only minimal assumptions involved. One method, Eclipse Mapping, takes an image reconstruction approach, requiring only minimal physically feasible assumptions about the shape of the pulsation patterns (like axial symmetry and periodicity across the stellar surface). Another more specific method, termed Direct Fitting, assumes generic spherical harmonics as eigenfunctions, and also allows in principle the determination of the orientation of the symmetry axis of the pulsations. We present our experience regarding the applicability of these methods to real data, with an account of the limitations and caveats that we have encountered during these developments. We also present a number of applications on systems observed by KEPLER (KIC 10661783, KIC 3858884).

A stochastic sampling method for the analysis of eclipsed pulsations

Mr András Bókon,
Department of Experimental Physics,
University of Szeged (Hungary)

Pulsations in eclipsing binaries offer a unique opportunity to get information about the surface intensity of the pulsation patterns themselves, with an exciting prospect of direct mode identification in addition to asteroseismologic analysis. One method is the direct modeling of the pulsations modulated by the eclipse phenomenon (Direct Fitting, DF), using spherical harmonics or as pulsation patterns. With the overwhelmingly large number of detected pulsation frequencies obtained with space observatories, however, the parameter space of the problems is also becoming too large to be tractable with conventional optimization methods. Therefore, I investigate the application of stochastic MCMC methods to sample the parameter space, in order to make the DF methods viable. The special configuration of discrete unordered parameters (the mode numbers) requires a special handling of them as so-called category variables. I report our experience with this approach obtained during tests on artificial data and application on real data (KIC 3858884), performed to examine the capabilities and limitations of the method.

The effects of mixing on accreted material

Dr Richard Stancliffe, Hull University (UK)

Mass transfer between binary stars is crucial to understanding a variety of classes of astrophysical objects. Beyond the problems of shifting mass from one star to another (as discussed elsewhere at this meeting) is the issue of what happens to material after it has been accreted. Does accreted material simply remain at the stellar surface, or can it be mixed by some process into the stellar interior? This issue is particularly important for those of us interested in studying nucleosynthesis in stars that are no longer around. In this contribution, I will discuss the role that processes like thermohaline mixing have in modifying the surface compositions of low-mass stars, and how it complicates using their abundances as probes of asymptotic giant branch nucleosynthesis. I will discuss what we think we know, and do not know, about the mixing of accreted material in carbon-enhanced metal-poor stars. I will then discuss the possible implications for more metal-rich systems, such as the barium and CH stars.

Binary star with a pulsating component

Dr Przemysław Walczak (with Prof Henryk Cugier), University of Wrocław (Poland)

Studying the close binary stars evolution pose a challenge for present day astrophysicists. The very complicated interactions between components hamper the interpretation of the observational data. Due to this, the binaries with a pulsating component(s) are particularly interesting since the seismic analysis can shed light on the physical processes occurring in the stars that undergo intensive mass and angular momentum exchange. Here, we present an attempt to model the surface chemical abundances (H,He,C,N and O) that can result from binary star interactions and rotationally induced mixing of elements using MESA computing code. Further constrains of the stellar structure of pulsating components are discussed.

THURSDAY 21ST JANUARY

Search for quiet stellar-mass black holes lurking in binary systems by asteroseismology from space

Prof Hiromoto Shibahashi,
University of Tokyo (Japan)

Stars with an initial mass more than ~25Msun are thought to ultimately become black holes. Then stellar-mass black holes should be ubiquitous but fewer than 20 have been found in our Galaxy to date, all of which have been found through their X-ray emission. In most cases these are soft X-ray transients --- low-mass X-ray binaries whose optical counterparts are late type stars filling their Roche lobes, leading to accretion onto black holes. In one case, the stellar-mass black hole is in a high-mass X-ray binary whose optical counterpart is an early type star. Its strong stellar winds are accreted by the black hole, producing X-ray emission. It follows that X-ray-quiet stellar-mass black holes exist in wide binary systems. The discovery of black holes in the optical through their gravitational interactions would be a major scientific breakthrough. Recent space-based photometry has made it possible to measure phase or frequency modulation of pulsating stars to extremely high precision. Such modulation is caused by orbital motion, and its analysis offers the lower limit for the mass of the companion to the pulsating star. If the companions are non-luminous and if the masses of the companions exceed the mass limit for neutron stars (~3Msun), the companions should be black holes. I will review the methodology, and analyses of some encouraging cases are demonstrated.

Tidal forcing and dissipation in binary stars

Prof Gordon Ogilvie,
University of Cambridge (UK)

Many stars experience low-frequency gravitational tidal forcing by their stellar or planetary companions. The tidal response of the star generally consists of wavelike and non-wavelike parts, with the wavelike part differing in character between radiative and convective regions and often being sensitive to the rotation of the star. Dissipation of the tide leads to evolution of the spin and orbit on astronomical timescales. I will discuss several mechanisms of tidal dissipation and their efficiency, including recent work on the effective viscosity of convective motions, as well as the dissipation of internal waves by linear and nonlinear processes.

An eccentric binary system TYC4038-693-1 with a pulsating component

Dr Erika Pakštienė,
Institute of Theoretical Physics and Astronomy, Vilnius University (Lithuania)

A binary star TYC4038-693-1 was discovered at Moletai Astronomical Observatory from photometric observations with 35/50cm Maksutov type telescope in 2016 (Pakstiene et al. 2019). Since then we have collected additional multicolour photometric observations of the system. The TESS has also observed TYC4038-693-1 in the 18th sector. New photometric observations show that the system has highly eccentric orbits. One of the components shows short periodic brightness variations intrinsic to d Scuti stars. Amplitude and frequency of these variations vary with time. An increased gravitational interaction and tidal phenomena were observed when the components moved close to the periastrons. We also obtained additional spectrometric observations with 165 cm telescope and high resolution Echelle type spectrograph at Moletai Astronomical Observatory. They allowed us to get radial velocity curves of the components, decompose their spectra and get some parameters of the components. Preliminary analysis has shown that the components of the system are relatively young (~0.8 billion years) with masses between 1.55 and 1.96 solar masses. As TYC4038-693-1 shows many phenomena intrinsic to binary systems, it makes this binary star a good candidate for further analysis of the system, testing interaction of components in eccentric binary systems, their evolution and behaviour of pulsating stars in such systems.

Tidal asteroseismology: an observational perspective

Dr Zhao Guo, University of Cambridge (UK)

More than half of all stars reside in binaries and tides can have a significant effect on stellar oscillations. I will review the effect of tides on stellar oscillations from an observational perspective, focusing primarily on intermediate and massive stars. Indirect evidence of tidal interactions is from the orbital synchronization/circularization of binary stars as well as the orbital decay and spin-orbit alignment of exoplanet host stars. Thanks to precise measurements of the space missions, we are now able to observe the manifestation of dynamical tides unambiguously: tidally excited oscillations (TEOs), which are on top of the overall heartbeat binary light curves from equilibrium tide. While Kepler observations offer us tens of A, F- type heartbeat binaries with TEOs, missions such as BRITE and TESS added more OB type heartbeat binaries with TEOs. The TEO amplitudes and phases can be used to identify the pulsation modes and constrain stellar parameters. Enhance tidal dissipation from resonance locking has been observed in a few binary systems. There has been possible evidence of tidally excited global Rossby modes and pure inertial modes in the convective core. New tidal phenomenon includes the tidally trapped p- and f-mode as well as tidally perturbed modes in circular/synchronized close binaries. We have entered a golden era of tidal asteroseismology.

Epsilon Cygni: a possible case of a very extreme heartbeat system

Mr Paul Heeren, ZAH-LSW
University of Heidelberg (Germany)

From a long-term RV survey of G and K giant stars at Lick Observatory and the SONG telescope we have identified, among others, a number of stellar binary systems that might harbor additional planetary companions. One peculiar case is the highly eccentric (e~0.93) binary system Epsilon Cygni, whose RV curve shows variations with a period of about 290 days that closely resemble the signal of a Jupiter mass planet orbiting the evolved primary component. However, the Keplerian elements of the putative planet's orbit undergo strong temporal evolution, especially during the periastron passage of the stellar companion; also, in extensive dynamical simulations of the system no stable solutions could be found. Therefore, we investigate alternative explanations for the RV signal, amongst them the possibility of the primary component being tidally excited during the close periastron flybys of the stellar companion. We compare the system to known heartbeat systems from the literature, and even though the separation between the two components in Epsilon Cygni is much larger as compared to all other heartbeat binaries, due to its very high eccentricity Epsilon Cygni might fall onto the extreme edge of the distribution of tidally excited systems. As many evolved stars are known to undergo oscillations with long periods between about 200 to 1500 days, there might be oscillation modes present in Epsilon Cygni that could be excited towards long-lasting dynamical tides. A more thorough analysis of the system would require modelling the composition of the evolved primary star in combination with the tidal influence of the stellar companion.

Single-sided pulsators

Prof Gerald Handler,
Nicolaus Copernicus Astronomical Center
Warsaw (Poland)

The single-sided pulsators are a new type of oscillating stars in close binary systems. They appear to pulsate principally in one hemisphere because their pulsation axes have been tilted into the orbital plane by the tidal forces exerted by a close companion star. At the time of this writing, we have discovered three of those systems in TESS space photometry data as well as noticed some related cases in the literature. Aside from all pulsators being Delta Scuti stars, and the orbital periods being shorter than two days, all those systems are different in terms of their pulsational behaviour, secondary star and Roche Lobe filling factor. We will present an overview of those stars, as well as our initial results and work in progress.

FRIDAY 22ND JANUARY

Machine learning in stellar physics

Dr Gregor Traven, Lund Observatory (Sweden)

What is machine learning? This topic covers a vast range of applications of mathematical algorithms on (observational) data. The astronomical community has already adopted many of such algorithms for diverse tasks that range from visualisation to classification to understanding the basic physics. It is obvious that with current and future facilities, we are facing an explosion of data, which calls for faster and more efficient analysis methods. This explains the popularity of machine learning (ML) algorithms, however, it is important to understand the advantages and limitations of any novel techniques, and it is also interesting to look behind the curtains into some details of how the actual algorithms work. We shall review a selection of utilities of ML algorithms on examples of different datasets. Most will be based on stellar spectra from large all-sky surveys such as RAVE, APOGEE, GALAH, but we'll also touch on other observations that provide insight into stellar physics, such as photometry and asteroseismology. An important and outstanding question in the context of analysis of astronomical data is how to provide reliable uncertainties of derived quantities, and so we will look at how different ML techniques address this issue. We'll also explore some details of how e.g. dimensionality reduction or different kinds of neural networks work. Finally, some recently developed methods will hopefully stimulate a discussion on where the future is taking us in terms of ML use in astronomy.

Augmented Sliced Wasserstein Distances

Dr Yunpeng Li, University of Surrey (UK)

While theoretically appealing, the application of the Wasserstein distance to large-scale machine learning problems has been hampered by its prohibitive computational cost. The sliced Wasserstein distance and its variants improve the computational efficiency through random projection, yet they suffer from low projection efficiency because the majority of projections result in trivially small values. In this talk, I will introduce a new family of distance metrics, called augmented sliced Wasserstein distances (ASWDs), constructed by first mapping samples to higher-dimensional hypersurfaces parameterized by neural networks. We show that the hypersurfaces can be optimized by gradient ascent efficiently. We provide the condition under which the ASWD is a valid metric and show that this can be obtained by an injective neural network architecture. Numerical results demonstrate that the ASWD significantly outperforms other Wasserstein variants for both synthetic and real-world problems.

Pulsations in faint blue stars

Dr Conor Byrne, Armagh Observatory (UK) and University of Warwick (UK)

Blue large-amplitude pulsators (BLAPs) are hot, high-amplitude pulsating stars which have been recently discovered by both the OGLE survey and the Zwicky Transient Facility (ZTF). It has been proposed that these objects are low-mass pre-white dwarfs and that their pulsations are driven by the opacity of iron-group elements. To verify the evolutionary status of these stars, a sequence of post-common-envelope stellar models were computed using the MESA stellar evolution code and the pulsation properties of the resultant low-mass pre-white dwarfs were examined through non-adiabatic analysis with the GYRE stellar oscillation code. By accounting for the effects of atomic diffusion and radiative levitation, it is shown that a large region of instability exists from effective temperatures of 30,000 K up to at least 50,000 K and at a wide range of surface gravities. This instability region encompasses both the OGLE pulsators and the ZTF pulsators, indicating they have a similar evolutionary history. The morphology of the instability region is found to be sensitive to assumptions made about the common envelope phase of evolution. This indicates that BLAPs may be a useful tool for developing our understanding of common envelope evolution. Estimates are made regarding the range of periods, masses, temperatures, and gravities in which further such pulsators might be observed in ongoing and future all-sky photometric surveys.

Non-radial pulsations in Hot Subdwarf B Stars

Dr Holly Preece, Max-Planck-Institut for Astrophysics (Germany)

Hot subdwarf B stars are He core burning objects which have lost their H burning envelopes through binary interactions. These stars have been predicted and observed to have non-radial oscillations. The majority of observed pulsators have gravity modes although some have pressure modes. A small sample of hybrid pulsators have also been discovered which exhibit both p and g modes. Serval sdBs have been observed with Kepler, K2 and Tess which yield high quality lightcurves. The analysis the lightcurves of pulsating sdB stars gives insight into the interiors of He core burning objects which are on their way to the white dwarf cooling track. This talk shall give an overview of the major results in the field.

Neutron star binaries and fundamental physics

Dr Arnau Rios-Huguet, University of Surrey (UK)

GW170817 was the first telltale detection of a neutron-star binary, a true multimessenger event appearing as a kilonova across the electromagnetic spectrum and with a distinct gravitational wave signal. This extraordinary event had several implications across physics, from cosmology to nucleosynthesis and, of course, to binary stars. In this talk, I will briefly review why neutron-star mergers are promising and how multimessenger signals provide insights on the structure of neutron stars. These insights complement existing developments in radio and X-ray astronomy, that probe compact objects in different ways. I will discuss how, ultimately, these joint efforts will help us determine the equation of state of dense matter and how, with this knowledge, we can probe the strong interaction.

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