5th Australian Exoplanet Workshop

"Australian Exoplanetary Science in the Era of K2, TESS and Gaia"

University of New South Wales
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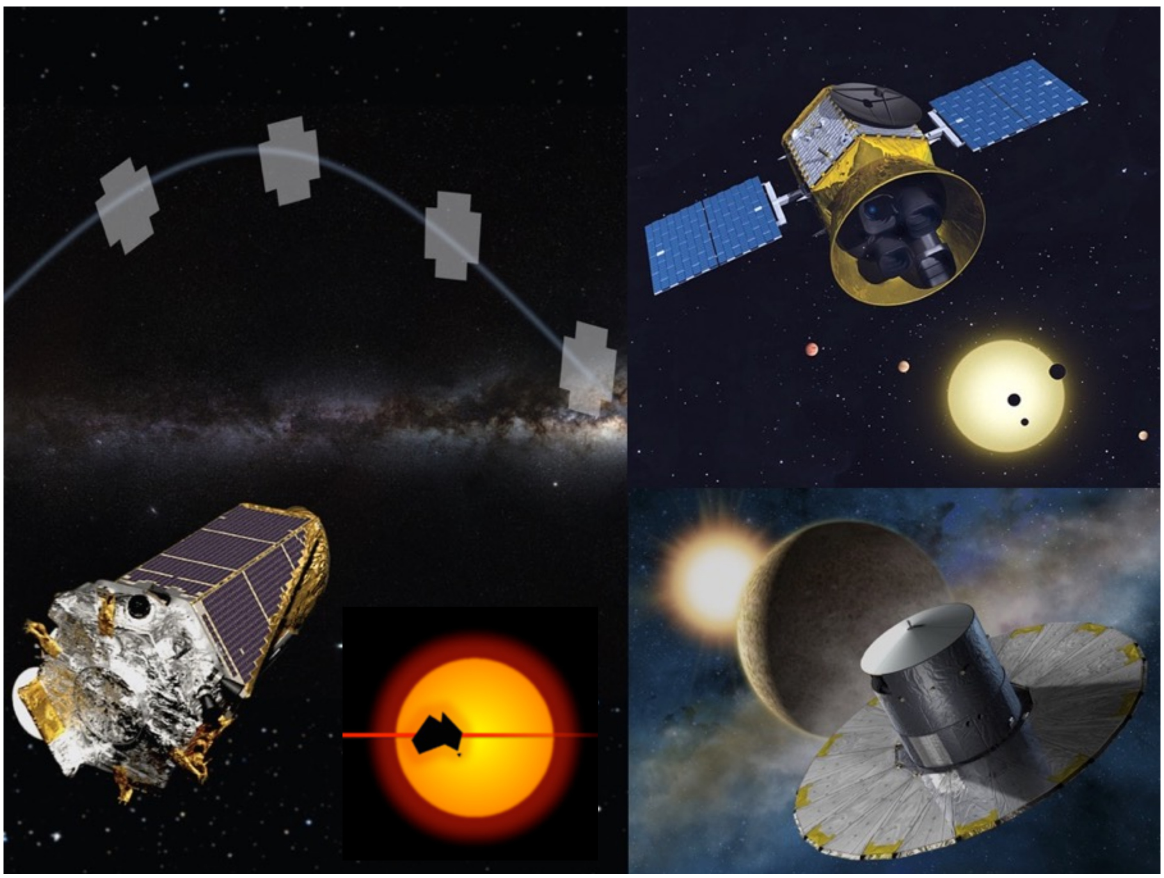

SOC: Phil Bland (Curtin), Brad Carter (USQ), Lucyna Chudczer (UNSW), Dan Huber (U Sydney, Chair), Mike Ireland (ANU), Charley Lineweaver (ANU), Sarah Maddison (Swinburne), Chris Tinney (UNSW)

LOC (UNSW): John Bentley, Lucyna Chudczer, Daniel Cotton, Jonty Marshall, Daniela Optiz, Rob Wittenmyer, Duncan Wright (UNSW, Chair)

Abstracts

Session 1: Transit & Radial Velocity Surveys

Jessie Christiansen (NASA Exoplanet Science Institute/Caltech):
Kepler/K2, TESS & opportunities for Australian Exoplanet Science (Invited)

Chris Tinney (UNSW):
Australian Doppler Capabilities for Exoplanetary Science in the K2/TESS era
Over the next five years, exoplanetary science will enter the global astronomy era as the K2 and TESS missions deliver an order of magnitude (or larger) increase in the number of planetary transit detections. All of these will become publicly available almost immediately. What capabilities will Australia have to exploit this freely available resource?

Duncan Wright (UNSW):
Planets around nearby M Dwarfs
I will discuss the future of M Dwarf planet searches in the context of the upcoming TESS mission. I will outline what TESS will be able to detect, and what we should do to ensure our upcoming spectrograph Veloce gets involved in the planet finding action. If there is time I will also include a brief outline of a new three planet system found around a nearby M Dwarf star with HARPS data.

John Bentley (UNSW):
Southern Hemisphere photometrically based M-dwarf catalogue
I will present my work in constructing a catalogue of probable M-dwarfs that would be suitable for large, multi-target surveys like FunnelWeb. For this, I have used photometry from the WISE survey. I will show that using WISE colours can decrease the amount of contamination from M-giants in a M-dwarf selection criteria.

Jinglin Zhao (UNSW):
CARMENES End-to-End Simulation
CARMENES (Calar Alto high-Resolution search for M dwarfs with Exo-earths with Near-infrared and optical Echelle Spectrographs) will perform high-precision (~1 m/s) radial-velocity (RV) measurements with long-term stability. Before its science survey starting in 2016, we run the End-to-End Simulation in both optical and near-infrared arms on a PHOENIX model M3 dwarf, of a time-series of 100 exposures distributed over 4 years and SNR=150 in J-band. Two sets of spectral data are simulated, one from a quiet star scenario (with Doppler shift only due to Keplerian motion), and the other from a spotted star (with Doppler distortions from one big co-rotating spot as a test case). Three planets are injected into the system: [K, P] = [13.6m/s, 666d], [5m/s, 7.5d] and [0.8m/s, 38.7d]. After calibrating and extracting the spectra and computing RVs using the CARMENES pipeline, we have recovered all the three planets in the quiet scenario by simultaneously fitting the candidates with periodogram analysis, and recovered the first two planets in the spotted star system by introducing RV models.

Session 2: Transit & Radial Velocity Surveys Continued

Timothy Bovaird (ANU):
An artificial Kepler dichotomy? Modelling Q1-Q16 Kepler detections with various inclination and multiplicity distributions
We challenge the assumptions present in previous efforts to model the ensemble of detected Kepler systems. These studies under-produced single-planet systems and invoked the so-called Kepler dichotomy, where Kepler stars belong to a dichotomous stellar population of `fertile' and `sterile' planet producing stars. We examine the model dependence of the Kepler dichotomy by using additional inclination and multiplicity distributions.

Daniel Huber (Sydney Uni):
Giants Orbiting Giants: A Search for Planets around Evolved Stars with Kepler/K2
While exoplanet transit surveys are increasingly focused on cool dwarfs, transiting planets orbiting red-giant branch (RGB) stars are largely unexplored. Due to their diversity in fundamental properties (masses, luminosities, chemical compositions), RGB stars are ideal targets to tackle two key unsolved questions in exoplanet science: the occurrence rate of gas-giant planets as a function of host star mass, and the role of stellar incident flux on the radius inflation of gas-giant planets. Additionally, RGB stars (and their planets) can be precisely characterized using asteroseismology. I will discuss an ongoing survey of low-luminosity RGB stars to detect transiting giant planets with Kepler/K2 and address the above science questions by combining exoplanet transits and asteroseismology.

Lucyna Kedziora-Chudczer (UNSW):
Characterisation of hot Jupiters by observations of their secondary transits with IRIS2

Rob Wittenmyer (UNSW):
MINERVA: The first year of robotic science and plans for world domination
The MINiature Exoplanet Radial Velocity Array (MINERVA) is fully operational at the F.L. Whipple Observatory in Arizona. I describe some results from our photometric observations, including the discovery of a disintegrating minor planet transiting a white dwarf. I also describe MINERVA-Red, located at the same site with the aim of detecting terrestrial-mass planets orbiting mid-to-late M dwarfs. Finally, I elaborate on the recently LIEF-funded MINERVA-Australis, a similar array of up to 6 telescopes array to be sited at USQ's Mt Kent Observatory for follow-up validation and multicolour characterisation of K2 and TESS planet candidates.

Joao Bento (ANU):
Update on the current status of the RHEA spectrograph
The detection of exoplanets using Radial Velocity (RV) measurements is commonly limited by the temperature and pressure stability of spectrographs. Additionally, noise from stellar activity is becoming increasingly important, particularly in giant stars, where the amplitude of pulsations is comparable to RV signals from hot-Jupiters. Thus, long-baseline RV measurements are required to understand the intrinsic pulsations of the host star and search for the planetary signals using asteroseismological analysis. This is impractical using large telescopes, but possible to do on bright stars with 0.2-0.4m class telescopes, provided they can be fitted with in-expensive high-resolution spectrographs. In this talk I will report on the current status of development of the RHEA spectrograph being developed at Macquarie University/ANU aiming to serve as the basis of multiple units on many small telescopes in the future.

Adam Rains (ANU):

Improved Light Coupling Efficiency for Spectroscopy on Small Telescopes

The RHEA spectrograph is an instrument currently under development at Macquarie University in Sydney and is expected to relocate to ANU/RSAA early next year. The instrument was built to be capable of long-baseline radial velocity (RV) observations on small telescopes, with the long ba! seline allowing for easier separation of a potential planet's RV signal from that of the stellar pulsations of its host star. This talk will detail the planned improvements for RHEA, specifically an upgraded optical fibre feed and miniature tip/tilt system. The new feed is intended to substantially improve the throughput of the telescope-spectrograph system through the use of a beam shaping technique (PIAA - Phase Induced Amplitude Apodization) and a multi-fibre Integral Field Unit (IFU) using a microlens array and single mode fibres (SMF).

Matthew Davie (UNSW):

Why you should look at your flat fields

The crew at HARPS have known that their wavelength solutions for their spectra are imperfect for a long time, and have done little about it. These imperfections have a substantial impact on measurements of radial velocity for planet-search purposes. I present a few ways to approach and resolve the issue as it appears in UCLES spectra.

Session 3: Solar System + Transit & Radial Velocity Surveys continued

Penny King (ANU):

The Solar System-Exoplanet Connection (Invited)

Haiyang Wang (ANU):

Consensus Elemental Abundances of the Bulk Earth and Proto-Sun

We present new estimates of the bulk elemental compositions of the Earth and proto-Sun. A heterogeneous set of literature values for the Earth's primitive mantle and core are combined into a concordance set of bulk elemental abundances of the Earth. The latest elemental abundances in CI chondrites and solar photospheric data are combined to estimate the present-day solar abundance. Diffusion corrections are made to get the bulk protosolar elemental abundance. The depletions of the Earth's highly and moderately volatile elements are quantified as a function of condensation temperature. We argue that these depletions may be our best generic proxy for the chemical relationship between a terrestrial planet and its host star.

Donna Burton (USQ):

Dating Active Young Stars

Age is an difficult stellar quantity to obtain accurate and reliable measurements for. Yet age is critically important in the search for a habitable planet. This talk will look at the current methodologies for establishing stellar ages, their advantages and limitations.

Dan Bayliss (Geneva Observatory):

Characterising transiting exoplanets with CHEOPS

CHEOPS (CHaracterising ExOPlanet Satellite) is a small (30cm aperture) space-based photometric observatory to be launched into low Earth orbit in 2017. CHEOPS will measure photometric signals from transiting exoplanets with a precision limited by stellar photon noise of

150 ppm/min for a 9th magnitude star. The primary science goal of the CHEOPS mission will be to characterize the structure of exoplanets with typical sizes ranging from Neptune down to Earth radius. For more information, please visit: http://cheops.unibe.ch
CHEOPS is the first S-class mission from ESA, and will have 20% open time. So the Australian community is encouraged to think of interesting projects and propose for time on CHEOPS.

Marcell Tessenyi (UCL):
Twinkle - a UK space mission to explore faraway worlds
The study of exoplanets has been incredibly successful over the past 20 years: nearly 2000 planets have been discovered, and along these discoveries fundamental parameters such as mass, radius and semi-major axis have been obtained. In the past decade, pioneering results have been obtained using transit spectroscopy with Hubble, Spitzer and ground-based facilities, which have enabled the detection of a few of the most abundant chemical species, the presence of clouds, and also ! permitted the study of the planetary thermal structure. Twinkle is a small, dedicated satellite designed to measure the atmospheric composition of exoplanets. Twinkle is a cost-effective spacecraft being built on a short timescale and is planned for a launch by 2019. The satellite uses an existing platform designed by Surrey Satellite Technology Ltd, and instrumentation built by a consortium of UK institutes. Twinkle will analyse >100 exoplanets in our galaxy and a few objects in our solar system. Its infrared spectrograph will enable observations of a wide range of planet types including super-Earths and hot-Jupiters. Some of the target planets are orbiting stars similar to our Sun and some are orbiting cooler red-dwarfs. For the largest planets orbiting bright stars, Twinkle will even be able to produce maps of clouds and temperature. The Twinkle instrument will be composed of a visible-IR spectrograph (between 0.5 and 5um) with resolving power R~300, and will orbit Earth on a sun-synchronous polar orbit. In this talk I will provide updates on the status of the project and discuss possible future collaborations. More information on Twinkle can be found on our website: www.twinkle-spacemission.co.uk

Giovanna Tinetti (UCL):
Decoding the light from other worlds in our Galaxy
It is now accepted that exoplanets are ubiquitous. However little is known about those planets we have detected beyond the fact they exist and their location. For a minority, we know their weight, size and orbital parameters. How do we progress from here? The planetary parameters mass, radius and temperature alone do not explain the diversity revealed by current observations. The chemical composition of these planets is needed to trace back their formation history and evolution, as it was the case for the Solar System. Pioneering results were obtained through transit spectroscopy with Hubble, Spitzer and ground-based facilities, enabling the detection of ionic, atomic and molecular species and of the planets thermal structure. With the arrival of improved or dedicated instruments in the coming decade, planetary science will expand beyond the narrow boundaries of our Solar System to encompass our whole Galaxy. In the next five years, the European Research Council funded program “ExoLights” at UCL will address the following fundamental questions: Why are exoplanets as they are? What are the causes for the observed diversity? Can their formation history be traced back from their current composition and evolution? The ExoLights team has developed state-of-the art statistical techniques to analyse exoplanet spectroscopic data and a comprehensive set of spectral retrieval models, to interpret exoplanet spectra. Core element of this program, is the design and planning of dedicated space missions for exoplanet spectroscopy, such as Twinkle (foreseen launch 2019) and the European Space Agency M4 candidate ARIEL (competing for launch in 2026). These dedicated missions will enable the use of the atmospheric chemical composition

as a powerful diagnostic of the history, formation mechanisms and evolution of gaseous and rocky exoplanets.

Session 4: Direct Imaging & Planet Formation

Barnaby Norris (U Sydney):
Direct imaging & Planet Formation (Invited)

Samuel Anastassiades (Monash):
Planet formation by gravitational instability: Are you cool enough?
Massive planet formation in outer regions of discs is a challenge to explain using the standard core accretion model. Gravitational instability offers a viable alternative. However, the basic criteria under which gravitational instabilities will lead to planet formation are not well understood. In particular, numerical simulations to determine the critical cooling time show a dependence on resolution. Here I present my attempts to understand and address this problem.

Jonty Marshall (UNSW):
Far-infrared and sub-millimetre imaging of HD 76582's circumstellar disk
Debris disks, tenuous rocky and icy remnants of planet formation, are believed to be evidence for planetary systems around other stars. The JCMT/SCUBA-2 debris disk legacy survey "Survey Of Nearby Stars" (SONS) observed 100 nearby stars, amongst them HD 76582, for evidence of such material. Here we present imaging observations by JCMT/SCUBA-2 and Herschel/PACS at sub-millimetre and far-infrared wavelengths, respectively. We simultaneously model the ensemble of photometric and imaging data in a self-consistent manner. At far-infrared wavelengths, we find extended emission from the circumstellar disk providing a strong constraint on the dust spatial location in the outer system, although the angular resolution is too poor to constrain the interior of the system. In the sub-millimetre, photometry at 450 and 850 micrometres reveal a steep fall-off that we interpret as a disk dominated by the smallest dust grains, perhaps indicative of a non-steady-state collisional cascade within the disk. A disk architecture of at least two physically distinct debris rings at 50 and 200 au, along with a very steep particle size distribution, is proposed to match the observations. The composition of the dust is briefly investigated, and we find no evidence that icy or carbonaceous material would represent the data equally well with particle size distributions and minimum grain sizes more akin to typical debris disks.

Elodie Thilliez (Swinburne):
Finding exoplanets via debris disc modeling
Planet(s) gravitationally interacting with a debris disc can significantly impact its dust distribution, therefore leaving observable signatures. By numerically modeling the disc asymmetries, it is possible to constrain the location and mass of the perturbing planet. HD115600 hosts the first disc discovered by extreme adaptive optic with the newest imager GPI. This disc exhibits a moderate eccentricity, as well as a modest projected offset of 4 AU. These features make HD115600 a good candidate for hosting a hidden exoplanet. In this talk, we will see how constraints on this potential exoplanet can be derived.

Peter Tuthill (Sydney Uni):
New technologies for exoplanet imaging
Exoplanetary detection has always been driven by the uptake of the newest technologies. Direct imaging has long been at the difficult end of this challenging field. This talk will outline some recent results, and prospects for tomorrow's imaging devices.

Session 5: Direct Imaging & Planet Formation Continued

Christophe Pinte (UMI-FCA, Chile):
Observing the first steps of planet formation with ALMA
The first steps of planet formation are believed to be the growth of initially small, micrometric dust grains and their decoupling from the gas phase via vertical settling and radial migration. Vertical dust settling is thought to be a general mechanism resulting in the concentration of dust in protoplanetary disk midplanes. Because of instabilities and enhanced densities, rapid dust growth, as well as pebble and boulder formation are expected to occur when high enough dust concentrations are reached at the midplane. Until recently, observational evidence of these mechanisms remain spare. In this contribution, I will present recent ALMA observations of HL Tau and HH 30 and will discuss them in details in the context of dust settling, highlighting the properties of the dust sub-disk at the midplane. Both objects show extremely an flat dust disk, which allow us to put quantitative constraints on the evolution of dust grain population and on the mechanisms of planet formation.

Daniel Price (Monash):
Planet formation in dusty discs
I'll discuss some highlights from our recent work on 3D simulations of dust/gas in protoplanetary discs. In particular, we show that the absence of spiral structures in the spectacular image of HL Tau taken with ALMA is consistent with the presence of planets when the dust/gas interactions are accounted for. I'll briefly cover some of our recent progress on the algorithms also.

Sarah Maddison (Swinburne):
More evidence of dust pile up and growth at planet gaps - and beyond!
The holy grail of planet formation is the detection of a very young plant in the process of forming. Gaps in disks provide tantalising hints of embedded planets and there are now numerous examples of transition disks with strong evidence of dust traps at the edges of gaps. The spectacular ALMA science verification image of HL Tau showing numerous gaps and rings in its disc, which has resulted in a flurry of models to explain the presence of multiple gaps and rings. In this talk I'll present recent ALMA observations that demonstrate grain size sorting and growth in transition disks, as well as some new 3D hydrodynamical simulations of a planet embedded in a gas+dust disc with migrating, growing and fragmenting grains. We identify for the first time a self-induced dust pile up for certain values of the dust fragmentation threshold for the collisional velocity. This feature, in addition to the easily detected planet gap, causes a second apparent gap that could be mistaken for the signature of a second planet. These dust pile up zones also occur without embedded planets and are prime locations for the formation of planetesimals.

James Tocknell (Macquarie):
The Effect of Non-Ideal Magnetohydrodynamics on Disc winds from Protoplanetary Discs
Protoplanetary discs, the precursors of planets, are of great interest with the recent discoveries of myriad extrasolar planets. Their physical conditions and kinematics help govern how planets form, so understanding these disks is vital for building models of planet formation. Jets and disc winds have significant effects on the evolution of protoplanetary discs. Current models of these outflows typically ignore non-ideal magnetohydrodynamic effects, but these are known to operate inside these discs, and affect the structure of these discs, for example suppressing magnetically-driven turbulence in the disc. In this talk, I will present preliminary results including non-ideal effects in models of disc winds.

Rajika Kuruwita (ANU):
Circumbinary protoplanetary disks and and their outflows
To date we know of 11 circumbinary planets around main sequence binary stars, but we know little about their actual formation. To understand the formation of these planets we much understand the formation of the binary star and the disk from which they form. In my recent work I have been carrying out magnetohydrodynamical simulations of the formation of stars and studying the outflows to determine an estimate for the lift time of these disk.

Session 6: Dynamics & Atmospheres

Jonti Horner (USQ):
Exoplanet dynamics & Atmospheres (Invited)

Rosemary Mardling (Monash):
Kepler and Celestial Mechanics: Mathematic's role in Unveiling Exoplanets
The Kepler space telescope was designed to observe a relatively crowded single patch of sky towards the Cygnus-Lyra region of the sky. Most of the 100,000 stars monitored before the stabilization wheels failed are therefore faint, so that while its incredibly precise photometry could measure flux variations as small as two parts in 100,000, allowing it to make thousands of potential planet discoveries of planets transiting their stars, confirmation of the planetary nature of these candidates by radial velocity followup (ie, by planet mass measurements) has only been possible for a handful of bright stars because of the extremely high-resolution spectroscopy required. Perhaps the most exciting Kepler discoveries are the multi-transiting systems; at least 2000 planet candidates have at least one transiting companion, with many in near-resonant or resonant configurations, including two Kepler stars harbouring 7 transiting planets. The transit timing of the multi-transiters is not periodic, with the mid-transit time occurring late or early according to the masses of the companion planets and their orbital characteristics. This allows us to use photometry alone to determine the mean density of planets, pure gold for the field as a whole. The few systems fully solved using transit timing variations use expensive N-body scans of the large parameter space involved. I will give an overview of my mathematical formalism which solves this problem thousands of times more efficiently, and which gives insight into the origin and evolution of planetary systems.

Daniel Dindas (Monash):

Transit Timing Variation: Plucking the planetary strings

A TTV signal is produced by the gravitational interaction between the transiting planet and another, perturber planet. Due to the form of the disturbing function it is possible to treat the interaction pair-wise therefore any other planets which may also be interacting can be ignored. The TTV signal contains within it all the information about the interaction between the two planets and therefore information about the perturbing planet's orbital elements, of specific importance is the sensitivity to the perturbers mass and eccentricity. The trick is then determining an analysis that allows for this information to be knowable to the observer. The very fact that the TTV's can be folded at the outer orbital period showing evidence for a continuous relation between the TTV's and the outer mean longtitude comes as a consequence of using transit data to sample the inner planet's orbit, as well as a non-rational period ratio. Since only a few harmonics of the disturbing function are excited by the gravitational interaction, such an expression can be quite accurately represented by as few as three Fourier terms. We know the amplitudes of the n:n harmonics are directly proportional to the mass of the perturber while the amplitudes of n+1:n harmonics are proportional to the product of the eccentricity and the mass of the perturber. It is therefore possible to extract the mass and eccentricity, avoiding any degeneracy between the two. The curve is also characteristic of the phases at epoch. The analytical expression for the smooth curve depends in a simple way on the harmonics contributing and the amplitudes of these harmonics are simple functions of all the orbital parameters.

Matthew Agnew (Swinburne):

Dynamical stability study of Jovian-hosting exoplanetary systems

A discrepancy between the proportion of Jovian planets in single and multiple planetary systems (specifically multiple systems in which the Jovian coexists with a superterran or smaller companion) suggests an observational bias may be hiding rocky planets in these systems. As such, Jovian-hosting systems are of interest as they may possess rocky planets in their habitable zones. In this talk, we look at planetary architectures of multiple planet systems with a focus on systems with known Jovian planets on orbits interior to, exterior to or partially overlapping the habitable zone. By running numerical simulations and deriving the stability maps for these Jovian-hosting systems, our preliminary results show that even for systems in which the chaotic region of the Jovian partially or entirely overlaps the habitable zone, there are still stable regions within the habitable zone in which rocky planets can remain, often at the mean-motion resonances and Lagrangian points of the existing Jovian.

Jeremy Bailey (UNSW):

HIPPI and the Polarisation of Exoplanets

We have built a new instrument called HIPPI (High Precision Polarimetric Instrument) with the aim of detecting polarised reflected light from exoplanetary systems. HIPPI has demonstrated a sensitivity of four parts per million in fractional linear polarisation. I will describe the instrument and our preliminary results on the polarisation of exoplanet systems. Modelling techniques used to predict the expected polarisation signals have also been developed by incorporating polarised radiative transfer into our VSTAR modelling code.

Daniel Cotton (UNSW):

Know the Star, know the planet: a polarimetricist's point of view

Polarimetry is a potentially powerful tool for understanding planetary atmospheres. Aperture polarimetry is being pursued to investigate the clouds of Hot-Jupiters - something that isn't possible with other techniques. With an aperture polarimetry technique the (assumed) unpolarised light of the star is collected along with light that is partly polarised as a consequence of being reflected off the atmosphere of the planet. The fraction of polarised light received from the planet varies with phase but is much less than the total light from the star. Thus many measurements are required at parts-per-million precision. Any polarisation from the star that might vary complicates the measurement. Yet, the polarisation of stars at the parts-per-million level is largely unknown. Recently we have conducted a survey of 50 of the brightest stars in the Southern hemisphere, finding many more of them to be polarised than previously known. In this talk I will give an overview of the results of the survey with an emphasis on the implications for exoplanet research.

Session 7: Dynamics & Atmospheres Continued

Brad Tucker (ANU):
Google - LUV
I will give an overview our new project, Google-LUV (Loon Ultra-Violet).With a private company, we plan to build a network of ultra-violet telescopes to survey both the dynamic and dark Universe. The telescopes will be flown on long-duration, high-altitude balloons - providing access to high cadence near-UV photometry, with the first balloon platform set for a launch at the end of 2016/early 2017. We will retrofit our balloons with small (20 - 30cm) telescopes operating in the near-UV (200 - 300nm). We will use the balloons to perform a wide-field, high-cadence UV survey. We are looking to develop the scientific goals and cases and are looking for people to participate.

Charley Lineweaver (ANU):
Where Should We Look for Life: the Gaia Hypothesis, Multilevel Selection Theory and the Problem of Defining Habitability
The search for life elsewhere in the universe has focused on two target areas: Earth-like planets in circumstellar habitable zones (CHZ) and SETI. Without a well-defined idea of what life is (and what intelligence is), it is difficult to have a well-defined idea of where to look for it. I will evaluate some of the assumptions underlying the! most common search strategies.

Posters

Jeremy Bailey, Lucyna Kedziora-Chudczer, Kimberly Bott and Daniel Cotton (UNSW):
Polarisation of Planets and Exoplanets
We present observations of the linear polarisation of two hot Jupiter systems with our new high-precision polarimeter HIPPI (HIgh Precision Polarimetric Instrument). By looking at the combined light of the star and planet we aim to detect the polarised light reflected from the planet's atmosphere. This can provide information on the presence of, and nature of clouds in the atmosphere, and constrain the geometric albedo of the planet. The method is applicable to both transitting and non-transitting planets, and can also be used to determine the inclination of the system, and thus the true mass for radial velocity detected planets.To predict and interpret the polarisation from such observations, we have also developed an advanced polarimetric modelling capability, by incoroporating full polarised radiative transfer into our atmospheric modelling code VSTAR. This is done using the VLIDORT vector radiative transfer solver (Spurr,

2006). The resulting code allows us to predict disc-resolved, phase-resolved, and spectrally-resolved intensity and linear polarisation for any planet, exoplanet, brown dwarf or cool star atmosphere that can be modelled with VSTAR. We have tested the code by reproducing benchmark calculations in polarised radiative transfer, and by Solar System test cases, including reproducing the classic Hansen and Hovenier (1974) calculation of the polarisation phase curves of Venus.

Simon Murphy (U Sydney), Hiromoto Shibahashi (U Tokyo) and Tim Bedding (U Sydney)
A Method for finding non-transiting Planets: Pulsational Phase Modulation
Kepler photometry has revolutionised searches for planets and the study of stellar oscillations alike. While Kepler's impressive planet haul focusses on transiting bodies, we have developed a method that utilises the stellar oscillations for finding planets that do not transit their host stars. It can be largely automated; we have applied it to thousands of stellar light curves and produced orbital parameters with robust uncertainties. Here's an overview of the Phase Modulation (PM) method.