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Detecting Planet Obliquity in Thermal Phase Curves

In the last 15 years observations of exoplanetary atmospheres have expanded greatly with both transmission spectra and broadband photometry, the latter of which now often encompasses at least one full planetary orbit. We have seen a parallel advance in the sophistication of theoretical models applied to these data, which now often take into account molecular chemistry, large-scale circulation, and cloud formation/dynamics. Still under consideration is the appropriateness of using complex physical models to explain data which suffer from low signal-to-noise and potential uncharacterized instrumental noise sources. Our recent work has analyzed all available full- and partial-phase light curves from Spitzer's IRAC with a model that considers only the minimum number of physical processes reasonably motivated by current data. In many cases this simple model captures phase offsets and amplitudes for both circular and eccentric exoplanets. However, the orientations of planetsâ€™ spin axes relative to their orbital planes can have a large influence on the observed light curves, despite such information currently not being constrained from observations. We show that, for a range of planet obliquity states, both the amplitude and phase offset of thermal phase curves vary significantly. Additionally, when the planetsâ€™ rotation is fixed to predicted rates, there exist high-obliquity states which can capture observable features, including phase offsets. We consider the Saturn-mass planet HD 149026 b as an example of a planet whose high core mass, formation, and evolution would be consistent with the high-obliquity fit from our model.

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Methodology to detect exoplanet transits in the project TAOS-2

The TAOS-2 project (Transneptunian Automated Occultation Survey) consists of 3
robotic telescopes with a primary mirror of 1.3 m in diameter each one, each telescope will
have installed a helium-cooled camera and an 80 Mpx detector controlled by 10 FPGAs.
This will allow images to be taken at 20 Hz of approximately 10,000 stars simultaneously.
The objective is to detect stellar occultations by small objects)(âˆ¼ 1 km in diameter) in
Kuiperâ€™s belt (âˆ¼ 43 UA). In addition, with a large amount of data that will be collected by the TAOS-2 project, it will be possible to carry out other studies outside the main objective of the project, one of them is to design a method to detect possible transits of exoplanets.

Ashley Baker (ashbaker@sas.upenn.edu)

Oxyometer for Exoplanet Characterization

With TESS and other ground-based surveys searching for rocky exoplanets around cooler, nearby stars, the number of Earth-size exoplanets well-suited for atmospheric follow-up studies will increase significantly, enabling the study of the planetsâ€™ compositions and their formation mechanisms. For atmospheric characterization, these systems will each still require a significant amount of observing time. As a result, JWST will only be able to target a small fraction of the most interesting targets, and the usefulness of ground based observatories will remain limited by telluric atmospheric absorption. Here we explore a new method for ground-based exoplanet atmospheric characterization that relies on simultaneous, differential, ultra-narrow-band photometry. The instrument uses custom-cut wedge prisms and a narrow-band interference filter that enables simultaneous observing over two 0.3nm full width at half maximum bands spaced 1nm apart. This design enables one band to overlap the 760nm oxygen band head, which can be accessible in systems with high line-of-sight velocities, while the other imaging band is centered on an oxygen-free continuum region. Given the expected planet output from TESS, we estimate that multiple systems discovered by the next generation of exoplanet surveys will be amenable to ground-based characterization by our instrument, which we call an oxyometer. We show that observations of an Earth-like planet orbiting an 8 magnitude M4 dwarf using an oxyometer on a 10m telescope can achieve a signal-to-noise ratio of 3 in eleven transits. We describe the design of our oxyometer and present a test detection of a 50ppm faux-transit signal in lab in addition to an on-sky photometry sequence to demonstrate the ease of use of the compact instrument design.

Domenico Barbato (domenico.barbato@inaf.it)

Two new giant planets in the HARPS-N metal-poor sample

The study of exoplanetary frequency in relation to the physical properties of their host stars has so far revealed interesting correlations such as the one between occurrence rate of giant planets and stellar metallicity ([Fe/H]). Giant planets are more common around metal-rich stars, their frequency rising from 2.36% around metal-poor stars to 5% around solar-metallicity stars and to 25% around stars having twice the metallicity of the Sun. Recent works also show that stars hosting hot Jupiters have higher metallicities than stars orbited by long-period giant planets. Further study on the relation between star metallicity and giant planet occurrence rate, and especially the search for the metallicity limit under which no giant planets are formed, is key in helping discriminate between competing planetary formation models.
We present the results of HARPS-N observations on metal-poor stars within the Large Programme GAPS to search for new giant planetary companions. We report the detection of two long-period giant planetary companions around primaries with [Fe/H] around four and seven times lower than that of the Sun. Our results are input for the numerical study of the global survey detection limits and for new assessment of the frequency of gas giants around low-metallicity stars.
The new giant planets found are good candidates for further observation and characterization by astrometric measurements such as those provided by Gaia, and the updated estimate on planetary frequencies can usefully inform and help coordinating new observational efforts.

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Forming Hot Jupiters

Since the first extrasolar planets were detected, the existence of hot Jupiters has challenged prevailing theories of planet formation. The three commonly considered pathways for hot Jupiter formation are in situ formation, runaway accretion in the outer disk followed by disk migration, and tidal migration (occurring after the disk has dissipated). None of these explains the entire observed sample of hot Jupiters, suggesting that different selections of systems form via different pathways. The way forward is to use observational data to constrain the migration pathways of particular classes of systems, and subsequently assemble these results into a coherent picture of hot Jupiter formation. We present constraints on the migratory pathway for one particular type of system: hot Jupiters orbiting cool stars ($T < 6200$ K). Using the full observational sample, we find that the orbits of most wide planetary companions to hot Jupiters around these cool stars must be well aligned with the orbits of the hot Jupiters and the spins of the host stars. The population of systems containing both a hot Jupiter and an exterior companion around a cool star thus generally exist in roughly coplanar configurations, consistent with the idea that disk-driven migratory mechanisms have assembled most of this class of systems.

Aida Behmard (abehmard@caltech.edu)

HiCannon: Application of The Cannon to Keck/HIRES For Data-Driven Spectroscopy of Cool Stars

Spectroscopic analysis of exoplanet hosts is necessary for determining stellar parameters and a vital step in characterizing exoplanetary systems. Because small, cool stars such as K and M dwarfs are good targets for finding small, cool planets and the focus of many future planet-detection surveys, establishing precise spectral modeling techniques for cool stars is of high priority. However, modeling cool stellar atmospheres is difficult because their optical spectra are filled with dense forests of molecular lines, making modeling via synthetic spectral libraries difficult. To address this, we apply The Cannon, a data-driven method of determining stellar parameters, to Keck High Resolution Echelle Spectrometer (HIRES) spectra of cool (<5200 K) stars. We evaluate The Cannon's ability to predict values for stellar temperature, radii, bulk metallicity, and possibly elemental abundances in the limit of fast-rotators and other stars with parameters pushing the edge of the HIRES sample. Our ultimate goal is to use Cannon-predicted stellar parameters to better characterize the cool star population and uncover correlations between cool star abundances and planet occurrence to constrain planet formation theories.

David Berardo (berardo@mit.edu)

Analyzing Spitzer follow-up of K2 planets in preparation for the transition to TESS

The Spitzer space telescope has been and continues to be a useful tool for following up planets discovered by the K2 mission. Due to its higher cadence of observation, it can significantly improve orbital parameters and ephemerides of K2 planets, as well as provide further insights into the properties of their atmospheres through studying their infrared phase curves. In this work I use Spitzer observations in the 4.5 um channel to analyze the HD106315 system, which is known to have at least two transiting planets on 9.5 and 21 day periods respectively. The lightcurves were detrended using the pixel level decorrelation (PLD) algorithm to remove correlated detector noise. The goal of this work has been not only to study this system in greater detail, such as searching for transit timing variations to probe the possibility of additional planets, but also to prepare for the transition from K2 to TESS. A 550 hour proposal has already been accepted to use Spitzer to follow up planets discovered by the TESS mission, allowing Spitzer to continue to bolster the discoveries of other missions and contribute to our knowledge of extrasolar planets. As there is no publicly available pipeline for reducing Spitzer data, this work represents an important first step in preparing for the data that will be obtained by Spitzer when following up TESS planets.

Trisha Bhowmik (Trisha.Bhowmik@obspm.fr)

Spectro-Polarimetric analysis of HD32297 debris disk

Debris disks are believed to be evolved class of circumstellar disks formed around young stars. Ground based telescopes such as SPHERE onboard VLT has successfully demonstrated its ability to discern faint disk features such as rings, clumps, etc with the help of high contrast imaging techniques. Classical and polarimetric imaging can deduce morphological and spectral characteristics to derive dust grain properties and put a constraint on planet-disk interaction. Given that young debris disks are faint compared to their host stars, their detection and classical imaging mostly relies on post-processing techniques like angular differential imaging (ADI), which, in turn, causes bias in the intensity map of the disk structure. Several types of models have been developed to solve for this bias and retrieve the spectral information of such disk features. Our procedure involves generating a model grid, processing it through an ADI algorithm, and fitting the result on data, channel per channel, to build the spectrum of either a part or the complete disk. Similarly, for the polarimetric images assuming the dust present are optically thin to rule out multiple scattering, the signal observed in the Stokes vectors are affected significantly due to the convolution with a point spread function (PSF). We generate a polarimetric model grid, process it through a PSF convolution and fit the model to the data to retrieve physical observable like surface brightness or contrast. Comparing these observables of classical images and polarimetric images we estimate the fraction of polarization. We will present our preliminary results obtained on debris disks HD32297 observed with SPHERE-DPI(Dual-Polarimetric Images) and total intensity images. The total intensity spectrum obtained for this disk confirms it to be a bright symmetrical disk, the spectrum is also visibly blue indicating towards particular grain characteristics (size, chemistry and distribution) which is being currently studied and will be discussed

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Extensible, Object-oriented Python Packages For Orbit-fitting

Open-source code bases are essential modern tools for maintaining consistency and accuracy across scientific analyses. Code bases that can be rapidly modified to keep pace with algorithmic and scientific advancement are especially necessary in exoplanet orbit-fitting, a constantly evolving field. To meet this need, we present orbitize! and radvel: fast, extensible, and open-source Python packages that streamline the orbit-fitting process. Both packages are written in object-oriented Python and C/C++, and are equipped with modern Bayesian statistical methods for noise treatment and efficient algorithms. Here, we show how radvel can be used to model stellar activity signatures in radial velocity data with Gaussian Processes, and how orbitize! can be used to rapidly calculate orbit posteriors for imaging astrometry covering a short orbital arc with the Orbits for the Impatient algorithm. We also discuss how the community can contribute.

Josh Briegal (jtb34@cam.ac.uk)

Extracting long period variability from NGTS light curves

I describe a general method, based on the autocorrelation function, for extracting periodicity in irregularly sampled time series data. I apply this method to photometric light curves from the Next Generation Transit Survey (NGTS) to extract long period variability.

Josh Briegal (jtb34@cam.ac.uk)

G-ACF - A generalised autocorrelation function for irregular time series

We present a generalisation of the autocorrelation function (ACF) by generalising the discrete lag to a continuous real parameter and introducing the notion of weight and selection functions. The new generalised autocorrelation function (G-ACF) is a versatile definition that can robustly and efficiently extract periodicity and signal shape information, independently of the process and the sampling. The G-ACF has a wide range of potential applications and will be useful in any quantitative science where irregularly sampled time series occur.

Cam Buzard (cbuzard@caltech.edu)

Ground- and Space-Based Detection of the Thermal Emission Spectrum of the Transiting Hot Jupiter KELT-2Ab

KELT-2Ab is a hot Jupiter transiting the F star, KELT-2A. In this work, we detect the thermal emission from the hot Jupiter by using the spectroscopic binary nature of the system to disentangle the planetary and stellar signals in high resolution NIRSPEC spectra. Furthermore, we measure Spitzer low resolution secondary eclipse measurements of the system. We combine both data sets to constrain KELT-2Ab's metallicity, C/O ratio, and incident stellar flux, which parameterizes heat redistribution in the atmosphere.

We see that while NIRSPEC analysis cannot provide many further constraints on the Spitzer data, it does provide roughly the same constraints on metallicity and C/O ratio. This validates techniques that aim to constrain atmospheric composition of non-transiting planets using high resolution ground based instruments.

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Using Exoplanet Climate Simulations to Constrain Astroecology Models

The field of astrobiology aims to identify other habitable worlds. To date, thousands of exoplanets with a diversity of properties have been discovered, some of which are potentially habitable [1]. Exoplanet habitability is primarily determined by surface climate conditions. The habitability of Earth, for example, is chiefly a consequence of continually (relatively) mild ambient temperatures [2,3,4]. Thus, on first order, exoplanet habitability must be constrained by surface temperature conditions.

Exoplanet temperature profiles are often explored with the use with the use of General Circulation Models (GCMs) [5]. GCMs take as inputs key orbital parameters to simulate the probable climate generated by a planet with such properties. Orbital eccentricity and obliquity regulate the received stellar radiative flux on a planet, thus these parameters drive surface temperature conditions [6] and habitability. For an Earth-like planet in the circumstellar habitable zone (CHZ) with variable eccentricity and obliquity, time-dependent surface temperatures may be significantly perturbed.

In this research, a modeling approach is outlined for which simulated temperature profiles of Earth analogs on variable eccentric and oblique orbits serve as environmental inputs for a previously developed astroecology model. The simulations are run with the program Resolving Orbital and Climate Keys of Earth and Extraterrestrial Environments (ROCKE-3D) [7], a fully-coupled 3-dimensional GCM developed at the NASA Goddard Institute for Space Studies.

The applied methodology will place eccentricity and obliquity limits for the habitability of Earth-like planets. CHZ exoplanets with these parameters will be recommended as high-priority targets for future missions (e.g. James Webb Space Telescope). Confirmed CHZ exoplanets found to be suitable for terrestrial organisms are termed habitable (concerning only temperature and liquid water). Further, these analyses will identify types of organisms viable to survive on a given exoplanet climate. Thus, we can exploit the known metabolic byproducts to identify potential sources of observable biosignatures of the recommended exoplanet targets.

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Search for Exoplanetary Transits in the Galactic Bulge

The study of exoplanets provides us with a greater understanding of planetary system formation, what are their structures and compositions. In this project, our aim is to search and characterize extrasolar planets in the Galactic Bulge and to establish whether there is a relationship with existing exoplanets in the Disk of the Milky Way.

This will be done using photometric catalogs through the K2 mission and VVV survey. With these data, we will search for exoplanets in this field using the transit technique. We present the discovery of five exoplanet candidates, in which three warm Jupiters and two hot Jupiters detected in the Galactic Bulge with K2 data. Our candidates have a period between 3.6 and 35.2 days. One of them is a planet orbiting a variable star. Here, we will report preliminary planet catalogs and their properties.

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Investigating Young Planetary Systems Through Their Debris Disks

Exoplanets detected in unexpected parameter spaces (e.g., hot Jupiters, super Earths) require us to reassess the classical planetary system formation and evolution theory that were based on the Solar System prototype. Many theories (e.g., planetary migration, in-situ formation) have been proposed to explain observed exoplanet properties. To test these theories and to improve our understanding of early planetary systems, I investigate young planetary systems during the early stages of formation and evolution through their debris disks. Many existed planet-disk interaction models assume that only one planet is sculpting the disk features, whereas observations of mature planetary systems (e.g., by Kepler) have revealed that many planets reside in multi-planet systems. I will present my work on building multi-planet models to characterize young planetary system properties (e.g., planet masses, orbital parameters, formation timescales) through their corresponding debris disk features (e.g., warps, spirals arms, gaps) induced by planet-disk interactions.

Shannon Dulz (sdulz@nd.edu)

Boosting the Yield of Direct Imaging Space Missions with EPRV Measurements

We are developing simulation tools to quantify how precursory radial velocity survey data can enhance the planet detection efficiencies of space-based direct imaging missions such as NASA's WFIRST and HabEx/LUVOIR. Linking together and extrapolating demographic information from multiple sources and planet detection methods, we generate a synthetic population for use in precise Doppler measurements that precede the observations conducted by forthcoming space facilities. To simulate a radial velocity survey of this population, our calculations incorporate realistic instrument parameters and noise models. Recovered orbital parameters are incorporated into a detailed planet yield calculation for a direct imaging mission based on the methods of Stark et al. 2016.

Jon Fernandez Otegi (jonfr17@gmail.com)

Exoplanet characterisation: linking theory & observations.

Despite recent improvements in our ability to characterise exoplanets, the knowledge of the planetary interior remains limited. Today, we aim to go beyond a simple estimate of the mean density of the planet and to provide information on the planetary internal structure. This is a challenging task due to the degenerate nature of the problem and the observational uncertainty. Here we aim to remove some of the degeneracy and explore under what uncertainties information about the planetary structure and composition can be derived. We employ a full probabilistic Bayesian inference analysis that allows to quantify the degeneracy of structural parameters for high dimensional parameter spaces. We identify the range of possible on composition and thickness of different planetary layers, and analyse how the model variability depends on the observed mass, radius and their uncertainties. Next, we investigate how different assumed mass-radius relations for exoplanets with only measured radii affect the determination of the internal parameters. Finally, we explore the theoretical uncertainty in the mass-radius relation for various compositions under different model assumptions and show that they can be comparable to the measurement uncertainties. We expect that accurate observations from upcoming space missions like TESS, ESPRESSO, NIRPS or SPIROU will further constrain our theoretical models and, lead to a better understanding of the compositions and internal structures of planets around other stars.

Cristilyn Gardner (cristilyngardner@outlook.com)

Characterizing Giant Exoplanets through Multiwavelength Transit Observations: KELT-9b

Multiwavelength observations of host stellar light scattered through an exoplanet's atmosphere during a transit characterizes exoplanetary parameters. Using the Wyoming Infrared Observatory 2.3-meter telescope, we observed primary transits of KELT-9b in the ugriz Sloan filters. We present an analysis of the phase-folded transit observations of KELT-9b using a Bayesian statistical approach. By plotting the transit depth as a function of wavelength, our preliminary results are indicative of scattering in the atmosphere surrounding KELT-9b.

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A Validation Tool for TESS Exoplanet Candidates

Over the next few years, TESS will detect thousands of exoplanets and even more eclipsing binaries. Due to the size of TESS's pixels, it is an inevitability that some will receive flux from more than a single star. In these cases it can be difficult to determine if a signal is due to a transiting planet around a target star or an eclipsing binary around a different star hidden within the aperture. But there is hope. Since TESS target stars are relatively bright and nearby, they are ideal targets for follow-up observation programs and large-scale stellar characterization missions (e.g., Gaia). By considering the information collected from these observations, we can identify and place constraints on the properties of all visible stars within a given TESS pixel and calculate the probability of each star hosting a transiting planet or eclipsing binary consistent with a given transit-like signal. By incorporating this process into a larger validation procedure, we can produce a tool that can reliably confirm or deny the existence of any exoplanet candidate.

Helen Giles (helen.giles@mac.com)

Validating Monotransits from Space Missions

Observed during Campaign 14 by the K2 mission, an object transited once across its star, lasting over 53 hours at a depth of 1.7mmag.

Following its discovery in the light curve, the likelihood of a false positive due to photometry, telescope performance and other astrophysical sources was determined; as well as performing immediate follow-up using CORALIE on the Swiss-Euler telescope in La Silla, Chile. This provided initial stellar parameters from the spectra and radial velocity measurements for eliminating any possible binary systems.

Between the spectra and the second Gaia data release, a lot was learnt about the host star, as well as beginning planetary mass determinations with the radial velocity data.

Additionally, more system parameters can be gathered by fitting the transit with Namaste (Osborn et al., 2016), a mono-transit fitting software which can estimate orbital period and other key planetary parameters.

I will present the discovery and validation process of this planet-like candidate from K2â€™s Campaign 14 (Giles et al., in prep), and the benefits of applying these techniques to other space-based missions such as

TESS, CHEOPS and PLATO â€” particularly for TESS who will only observe large sections of the sky for short periods of time.

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Simulating Planetary Systems within Star Clusters

We perform simulations to model the evolution of multiple open star clusters, each with planetary systems about some fraction of their stellar population. Combining the facts that about 50% of stars in the Universe are suspected to have formed within clusters and that the rate of exoplanet-detection has boomed within the last decade highly motivates the study of how planetary systems can coexist with their stars amid a clustered environment. We observe how various initial conditions affect the perturbations of planetary systems. In each simulation, we vary parameters including the number of stellar systems, density of the star clusters, distribution of stars and stellar masses, and orientation of planetary systems. Calculations for each simulation are continued for a bit longer than it takes for the cluster to reach dynamical equilibrium. We generate distributions of semi-major axis, periapsis, eccentricity, and inclination in order to more clearly study the evolution of perturbation per planet with respect to each orbital parameter.

Gloria Guilluy (gloria.guilluy@edu.unito.it)

High resolution day-side spectroscopy of the hot gas giant HD 102195b

Recent observations of the transiting hot Jupiter HD 189733b with the GIANO infrared (0.9-2.45) Î¼m spectrograph at the Telescopio Nazionale Galileo have successfully proven that a 4-m class telescope with a performing high-resolution spectrograph can successfully study the atmospheres of exoplanets at high spectral resolution (R~50,000). Here we report on dayside spectroscopy observations with GIANO of the non-transiting hot giant planet HD 102195b, aimed at detecting water vapour in its atmosphere. We employ a technique to disentangle the Doppler-shifted planet spectrum (whose individual lines are resolved at high spectral resolution) from the stationary telluric/stellar components. We then extract the planetary signal by cross-correlating the residual spectra with template models of the planet atmosphere computed through line-by-line radiative transfer calculations, and containing molecular absorption lines from water vapour. Based on this analysis, we present a detection of water in the atmosphere of HD102195b, and a first estimate of the planet's true mass and inclination angle of the orbital plane.

Richard Hall (rdh47@cam.ac.uk)

On the Feasibility of Intense Radial Velocity Surveys for Earth-twin Discoveries

The detection of an Earth-mass planet in the habitable zone of a solar type star will be a ground breaking discovery. Current instruments are just shy of the precision needed to make these detections, and we are still confounded by the quasi-periodic stellar signals. The HARPS3 instrument is designed to have the measurement precision required to make this discovery, and the Terra Hunting Experiment will have a unique and intense observation schedule to help combat the stellar signals.

I present an end to end simulation of HARPS3 radial velocity data and use a multi-nested Bayesian analysis package to find the planetary candidates within the data. We factor in the full 3D Keplerian system architecture, realistic stellar noise, a proposed observation schedule and location specific weather patterns for our entire 10 year survey. I will discuss our promising results in the context of detecting long period earth planets and compare them to simulated results of a typical radial velocity survey. We also include the results of a continuous data series, representing the space-observatory case.

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Kepler Planet Occurrence Rates for Mid-Type M Dwarfs as a Function of Spectral Type

Previous studies of planet occurrence rates have largely relied on photometric stellar characterizations. We present new spectroscopic observations of 333 M dwarfs in the primary Kepler field, which have allowed us to constrain spectral type, temperatures, and in some cases metallicities for these stars. Combining our data with Gaia parallaxes, we have computed precise (~3%) stellar radii, and present updated planet parameters and planet occurrence rates for mid-type M dwarfs. With our refined spectral classifications, we further compute occurrence rates for spectral types M3 V, M4 V, and M5 V, and find an increasing trend of planet occurrence toward later mid-type M dwarf spectral types. With our refined radius measurements, we also find Kepler-1649 b to be an Earth-sized planet receiving similar insolation flux to Earth.

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Irregular Satellite Collisions: A Formation Mechanism for Circumstellar Debris Rings

Irregular satellites are the minor bodies of Jovian planets with long semimajor axes, large eccentricities, and high inclinations. They have been found to be highly collisionally evolved within our own Solar System, having lost $\sim$99\% of their starting mass ($\sim$0.001 lunar masses) over the last 3.9 Gyr. In this paper, we investigate the plausibility of irregular satellite collisions producing the dust found in circumstellar debris disks such as Fomalhaut and AU Microscopii. We performed numerical integrations taking into account both gravitational forces and radiation pressure. We find that a grain size of 5 microns ($\beta \approx 0.02$) is the dividing line between radiation pressure being just strong enough to perturb dust into spreading into a ring-like structure around the orbit of the planet. 5 microns is also the dividing line between a disk primarily composed of dust grains in low-eccentricity orbits ($s > 5\ \mu$m) and a disk primarily composed of dust grains in high-eccentricity orbits ($s < 5\ \mu$m). Power law fits to the radial density profile were found for each class of disks, with $s > 5\ \mu$m debris disks having an index of -8 and $s < 5\ \mu$m debris disks having an index of -4. We find characteristic widths of our debris rings consistent with the usual definition of narrow rings, namely $\Delta R/R \le 0.5$, with our rings being closer to the anomalous cases of Fomalhaut and HR 4976A of $\Delta R/R \sim 0.1$.

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The Effect of CCD Straps on TESS Photometry

The presence of metal "straps" on the TESS CCDs systematically changes the photometric response of 11% of all detector pixels. Each set of straps introduces a wavelength-dependent increase in response along with pixel-to-pixel modulation as a point source moves across. These variations will be correlated with pointing jitter and orbital motion, and are a significant source of noise for cooler stars. Fixed flat-fielding will not fully account for this effect; other ways to reduce strap noise include tuned flat fields and decorrelation techniques.

Vedad Hodzic (vxh710@bham.ac.uk)

WASP-128b: a short-period brown dwarf transiting a G0V host

Transiting brown dwarf (BD) companions to main-sequence stars are benchmark objects for characterising substellar objects. BDs on orbits ~< 0.3 AU are known to be rare around FGK stars, termed the brown dwarf desert. Only about a handful of BDs have been found from wide-field exoplanet transit surveys, despite the surveys being uniformly sensitive to companions throughout the BD desert.

In this context, we report the discovery of WASP-128b: a BD transiting a Sun-like star on a 2.2 day orbit, being amongst the first BDs transiting a G dwarf. Following the detection of a periodic signal in WASP data, we obtained spectroscopy from CORALIE and HARPS and follow-up transit light curves from the TRAPPIST and Euler telescopes. A combined analysis of the data reveals a mass, radius, and density of 37.5 +- 0.8 Mjup, 0.93 +- 0.02 Rjup, and 57 +- 3 g cm-3 for WASP-128b, placing it in one of the driest parts of the BD desert. Its position in the mass-radius diagram further hints towards two distinct populations -- high- and low-mass BDs. Moreover, evolutionary models may show tentative disagreement for the radius, which may hint at inflation for WASP-128b.

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The Gemini Planet Imager View of the HD 32297 Debris Disk

The HD 32297 debris disk system consists of a young (<30Myr) A-star surrounded by both a dust disk resolved at near-IR to mm wavelengths and a gas disk detection. In previous observations, the nearly edge-on geometry has been traced over size scales from ~50 AU to 100â€™s of AU with scattered light, thermal imaging and mm mapping with several indications that the disk is not axisymmetric. Extreme adaptive optics imaging from the ground enables the highest spatial resolution and highest contrast imaging of the scattered light component of the disk, and we present Gemini Planet Imager (GPI) H-band total intensity and polarized intensity imaging to investigate the disk structure. Previous studies have suggested complex radial structures such as double rings1, but there is uncertainty about the nature of this result due to the possibility of artefacts introduced in the PSF subtraction routine. To address this important structural question of the presence or absence of a disk gap, the GPI H-band data were processed with three independent techniques â€“ the standard pyKLIP algorithm used in the GPIES planet search, the RDI (Reference Differential Imaging) PSF-subtraction routine developed for GPI data, and a mask-and-interpolate procedure. Based on the initial results of the study, ADI reductions produced a gapped structure on the NE side of the disk, but both the RDI and mask-and-interpolate procedures do not produce a gap in surface brightness. An initial polarization fraction map of the disk is also created. The bright, edge-on nature of the disk makes it a prime target for upcoming JWST observations and has already been approved as a GTO target.

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Image Processing Methods for Exoplanet Detection in Starshade Observations

A starshade is a promising instrument for the direct imaging and characterization of exoplanets. One challenge is considering how detector noise, starshade defects, and misalignment (dynamics of the starshade system) degrade the signal to noise ratio (SNR) and contrast. No current image processing methods have been specialized for images produced by a starshade system (simply referred as starshade images later). We develop a method, based on generalized likelihood ratio test (GLRT), for detection and characterization of planets from a single starshade image or multiple starshade images. This paper describes the GLRT model and its preliminary results for simulated images with starshade shape error, dynamics, detector noise and starshade rotation included. The planets are detected with low false alarm rate, planet positions are accurately estimated, and planet intensities are reasonably estimated. In the future, the methods will be further tested for simulated images with more error factors included and more advanced imaging models.

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Using the UKIRT Microlensing Survey as a Pathfinder for WFIRST

Gravitational microlensing as a method of exoplanet detection is best suited to detecting planets of all masses located just beyond the snow line. This region of parameter space is largely unexplored, and it is necessary to detect many more planets via large microlensing surveys in order to understand these understudied planets. Our project utilizes the ground-based United Kingdom Infrared Telescope (UKIRT) as the first near infrared (NIR) microlensing survey to explore this parameter space. Preliminary results from Shvartzvald et al. 2017 presented five highly extinguished UKIRT microlensing events near the Galactic bulge (i.e. where $|b| < 2$) and provided initial constraints to the NIR event rate. As a follow up to this study, we inject a multitude of mock stars with simulated microlensing signals into real UKIRT observations taken between 2015 and 2017. We then utilize a modified UKIRT pipeline to extract the light curves of these mock stars, from which we aim to derive the UKIRT detection efficiency and eventually the NIR event rate per square degree to a precision of ~10%. Information on event rates in the NIR is crucial for informing mission design specifications, and prepares for the upcoming Wide Field Infrared Survey Telescope (WFIRST).

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The Origin of Kepler-419B: A Path to Tidal Migration Through Secular Eccentricity Modulation

We test the high-eccentricity tidal migration scenario for Kepler-419b, a member of the eccentric warm Jupiter class of planets whose origin is debated. In its current configuration, the outer perturber (Kepler-419c) cannot excite the eccentricity of the warm Jupiter high enough to undergo tidal circularization; however, if a third giant planet exists in the system (planet d), it could periodically boost the eccentricity of the inner planet enough for high-eccentricity migration to occur. We explore the parameter space of this potential third giant planet using a suite of 3395 N-body simulations with a range of initial conditions. From the results of these simulations we can rule out this mechanism for much of the parameter space of initial planet d conditions. However, for a small range of parameters (masses between 0.5 and 6 MJup, semi-major axes between 4.5 and 7.5 AU, eccentricities between 0.2 and 0.35, and mutual inclinations near 0Â°) an undiscovered planet d could periodically excite the eccentricity of Kepler-419b without destabilizing the system over 1 Gyr while producing a currently undetectable radial velocity signal.

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Exoplanet Research at the University of Wyoming

The Transiting Exoplanet Survey Satellite (TESS), launched in Spring 2018, will detect thousands of new exoplanet candidates. These candidates will need to be vetted by ground-based observatories to rule out false positives. The Observatories at the University of Wyoming are well-positioned to take active roles in TESS Follow-Up Observing Program (TFOP) Working Groups. The 0.6-m Red Buttes Observatory has already demonstrated its capability to do precision photometric monitoring of transiting exoplanet targets as a participant in the Kilodegree Extremely Little Telescope Follow-Up Network (KELT-FUN). A new echelle spectrograph, Fiber High-Resolution Echelle (FHiRE), being built for the 2.3-m Wyoming InfraRed Observatory (WIRO), will enable precision radial velocity measurements of exoplanet candidates. Over 180 nights/year at both observatories will be available to our team to undertake follow-up observations of TESS Objects of Interest (TOIs). We anticipate making significant contributions to new exoplanet discoveries in the era of TESS.

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ROCKE-3D: The Effects of Rotation Rate on the Surface Temperature of Terrestrial Worlds

Building our understanding of how fundamental planetary properties drive climate not only grants insight into our own planet, but allows us to speculate on the diversity of climates on worlds outside of our solar system. Planetary rotation rate has a significant effect on atmospheric circulation, where the extent of the wind cells (e.g. Hadley cells) are determined in part by the strength of the Coriolis effect. Previous studies have shown that clouds tend to congregate around the substellar point of slowly rotating aquaplanets, thus increasing the planetary albedo and decreasing the surface temperature at that point, subsequently extending the inner habitable zone to smaller orbits. Because of the different heat capacities and albedos of land and ocean, we expect that introducing a land mass will have a significant effect on the overall climate. In this study we adopt the continental configuration of the Earth to study the effects of slow rotations and increased insolations on the climate of an Earth-like world using the Goddard Institute for Space Studiesâ€™ ROCKE-3D General Circulation Model. Model results show that at current solar insolation, the average global surface temperature decreases by 9 CÂ° from 1x to 256x the rotation period of the Earth (i.e. increasingly long days). For a given insolation, the total average precipitation decreases with slower rotations. However, the average precipitation over land increases with slower rotations by up to 2.4 mm/day. In future studies we will obtain sub-day averages to analyze cloud behavior.

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Stellar and planetary characterization of two Kepler multi-planet systems from high-quality Gemini/GRACES spectra

Based on GRACES high resolution and high signal-to-noise ratio spectra obtained at Gemini North, we present the first detailed chemical abundance analysis of two Kepler evolved multi-planet hosting stars. We determine atmospheric parameters and chemical abundances of 20 elements Â (Li, C, N, O, Na, Mg, Al, Si, Ca, Sc, Ti, V, Cr, Mn, Co, Ni, Cu, Zn, Y, Â and Ba) Â from equivalent widths and synthesis analysis. In addition, from these new precise fundamental parameters, we derive refined stellar and planetary physical properties.

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Enigmatic AD Leo: a planet, a star spot, or both?

If our goal is to detect exoplanets, the amplitude of a periodic signal present in Radial Velocity (RV) data should be both time- and wavelength-independent. However, an on-going issue present is our limitation in both time and wavelength space. Perhaps the time baseline is not long enough to prove the consistency of the signal; or the wavelength range is not wide enough to justify that the signalâ€™s amplitude is persistent over all wavelengths. Essentially, we are not getting the full picture, and stellar activity, especially in M dwarfs, can mimic a planetary signal if a given time-wavelength subspace is not adequate enough.
In an attempt to address the wavelength coverage, the instrument CARMENES consists of two separate high-resolution echelle spectrographs, covering the VIS and NIR wavelengths from 520-960 nm and 960-1710 nm, respectively. Therefore, it can aid in determining whether a signal is truly due to a planetary companion or due to activity in the star itself. An additional tool is to look at the ChRomatic IndeX (CRX), where a correlation between the RV and the CRX indicates stellar activity.
A stellar target proved to be interesting to study is AD Leo, a 4.5 M dwarf known to be highly active. The literature reports a 23 m/s signal with a period around 2.23 days using HARPS, whose wavelength range is 383-690 nm and therefore bluer than CARMENES. The amplitude of the signal was shown to be relatively consistent throughout the wavelengths of HARPS and a CARMENES campaign for AD Leo was carried out to conclude whether or not the signal continues to be consistent. The CARMENES data in the VIS shows

the periodicity of 2.23 days with a similar semi-amplitude and phase, even though it is taken 10 years after the HARPS data, which would be consistent with a planetary signal. However, there is a clear correlation between the RV and the CRX, which is an indicator for stellar activity. In addition, the NIR shows a slight decrease in the amplitude of the signal. Here, I present a discussion on this 2.23 day periodic signal considering two possible scenarios: either the signal is due to stellar activity that has consistently stayed around for 10 years, or it is actually a planetary signal mixed with RV variations from stellar activity.

Blaise Kuo Tiong (kuotiong@gmail.com)

Designing and building an ultra-stable single mode fiber spectrograph for adaptive optics assisted observation in the infrared

Ever more precise radial velocity measurements are needed to observe potential earth-like exoplanet targets that are beyond the range of current generation high resolution echelle spectrographs. Meanwhile, extreme adaptive optics systems at 8 meter class facilities have made ground based observations possible at the diffraction limit. In the field of Doppler spectroscopy, one way to take advantage of these AO capabilities is by the development of ultra-stable fiber fed spectrographs. Using the single mode fiber feed from a facility's extreme adaptive optics system has advantages in removing modal noise, reducing instrument size, enabling superior environmental control and consequently costs. We report on the design and challenges in building an ultra-stable spectrograph for the near infrared range. We also present results from characterization of the infrared detector chosen for the instrument, a Princeton Infrared Technologies 1280SciCam. The design wavelength range is 650 to 1500 nm.

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Characterizing Exoplanet Atmospheres with the WFIRST Optical Coronagraph

WFIRST-CGI is a NASA technology demonstration mission charged with demonstrating key technologies for future exo-Earth imaging missions in space. In the process, it will obtain images and low-resolution spectra of a handful to a dozen extrasolar planets and protoplanetary disks. Its unprecedented contrast levels in the optical will provide astronomers' first direct look at mature, Jupiter-sized planets at moderate separations. This paper addresses the question: what science can be done with such data? An analytic noise model, informed by the on-going engineering developments, is used to compute maximum achievable signal-to-noise ratios and scientifically viable integration times for hypothetical star-planet systems, as well as to investigate the constraining power of various combinations of WFIRST-CGI photometric and spectral observations. This work introduces two simple models for planetary geometric albedos inspired largely by the Solar System's gas giants. The first planet model is a hybrid Jupiter-Neptune model, which separately treats the short and long wavelengths where chromophores and methane dominate absorption, respectively. The second planet model fixes cloud and haze properties in CoolTLusty to match Jupiter's albedo spectrum, then perturbs the metallicity between 1 and 30 times solar levels. MCMC retrievals performed on simulated observations are used to assess the precision with which planet model parameters can be measured subject to different exposure times and wavelength coverage.

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DARKNESS: A MKID-based Integral Field Spectrograph for High-Contrast Observations at Palomar Observatory

We present preliminary results from DARKNESS (the DARK-speckle Near-infrared Energy-resolving Superconducting Spectrophotometer), an integral field spectrograph currently operational behind the

PALM-3000 extreme AO system and the Stellar Double Coronagraph at Palomar Observatory. DARKNESS is the first IFS to utilize optical/near-infrared Microwave Kinetic Inductance Detectors (MKIDs) for high-contrast imaging. MKIDS are photon-counting detectors with microsecond time resolution which will enable new wavefront control techniques. We present the design and characterization of the instrument as well as on-sky results.

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Detecting Unresolved Binaries in Exoplanet Transit Surveys with Speckle Imaging

Exoplanet transit surveys, such as Kepler/K2, have discovered thousands of planets orbiting other stars and shown that planetary systems are remarkably common. While many exoplanet searches target only single stars or very wide binaries, Kepler was relatively unbiased to stellar multiplicity, resulting in the discovery of planets orbiting one or both stars in a number of binary systems. However, as the impact of stellar multiplicity on planet occurrence is not well understood and many binaries remain unresolved in such surveys, planet properties and population statistics are, in general, determined as if all stars are single. Not accounting for the effects of stellar multiplicity statistically biases planets toward smaller radii and gives rise to systematic errors in planet occurrence rates and completeness corrections. Detecting unresolved stellar companions can mitigate some of these biases and help us understand the fraction of exoplanets found in binaries. Using high angular resolution speckle imaging we detect stellar companions within ~1 arc second of Kepler\K2 (and soon TESS) planet candidate host stars in order to validate planets and determine the binary fraction of exoplanet host stars.

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Towards A Student-led TTV Research Program at UND

Efforts are currently underway at The University of North Dakota to establish an exoplanet research program. The UND Space Studies Observatory houses two 16-inch telescopes, which are routinely used for astrometric, photometric, and spectroscopic observations, including the transits of hot Jupiters to model-fit light curves and extract mid-transit times for the purpose of TTV analysis. The past two years have been dedicated to demonstrating the suitability of UNDâ€™s observatory for continued exoplanet transit observations, and as such, has proven a success. Over the next two years, the goal is to gather the necessary experience to create and develop a sustained TTV research program. Telescope operation, observations, data reduction and analyses of transit data is envisioned to be conducted by students and the output of these efforts would yield contributions towards a longer baseline of transit timing data, journal publications, and a sustainable production of trained exoplanet astronomers.

The first steps in establishing a dedicated TTV program are: 1) identifying the full range of exoplanets (radius, orbital parameters) whose transits are within the capability of UNDâ€™s telescopes; and 2) producing a streamlined data reduction and modeling pipeline. To meet the first objective, observations of a range exoplanets are scheduled to begin March 2018, building on an existing small set of hot Jupiter observations obtained between March â€“ November 2016. In addition, data reduction using IRAF and model fitting routines using Python have already been created and successfully used to analyze the transits of hot Jupiters (McCloat 2017). Despite this progress, additional effort is necessary towards developing a more robust pipeline that can perform the reduction and analysis efficiently and more autonomously. The expected products of this research would be light curves for a variety of exoplanet types from which the planet parameters, including mid-transit times and periods, can be extracted and the limiting precision of UNDâ€™s telescopes identified.

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Techniques for Finding Close-in, Low-mass Planets around Evolved Intermediate Mass Stars

Evolved intermediate mass (IM) stars (M > 1.3MSun) have high occurrence rates of Jupiter-mass planets with predominately large semi-major axes (a > 1.0 AU). There is a prominent paucity of close-in (a < 0.6 AU), intermediate period (5 < P < 100 days), low-mass (M < 0.7MJup) planets, known as the â€˜Planet Desertâ€™. Current radial velocity methods have yet to detect these close-in, low-mass planets around evolved IM stars because the planetary signals could be hidden by the (5-10) m/s radial velocity variations caused by p-mode oscillations. We find that by implementing an observing strategy of taking 3 observations per night separated by an optimal cadence, which is a function of the p-mode periods and amplitudes, we can average over the stellar jitter and improve our sensitivity to low-mass planets. We find that our method decreases the RMS of the stellar jitter due to p-modes by a factor of 3 over current single epoch observing strategies used for subgiant stars. Our observing strategy provides a means to test whether the Planet Desert extends to lower masses.

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Light -curve Analyses on TRAPPIST-1 d & e for Mass Estimation

TRAPPIST-1 system is one of the most interesting targets for detail observation. Small seven planets are orbiting very closely (< 0.1au) around a tiny M-dwarf star, and three of its planets (e, f, g) are thought to orbit inside the star's habitable zone. For further discussion about their habitability, it is important to know their bulk densities and compositions, using their accurate radii and masses. Radial velocity method is difficult to use for TRAPPIST-1, and instead we are using Transit Timing Variation(TTV) method for the planets mass estimation.

Using the MuSCAT camera at the Okayama Astrophysical Observatory, we observed consecutive transits of TRAPPIST-1 d & e in z-band. We analyzed the derived light-curve by model fitting, and as a result, we were able to add one new data point to each TTV data set of TRAPPIST-1 d and e. From this study, we can restrict the masses of the planets which are in orbital resonance with TRAPPIST-1 d and e.

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The SPECULOOS Pipeline for Detection of Planets Transiting Ultra-Cool Dwarf Stars

Working alongside research teams in Cambridge (UK) and Liege (Belgium), my research has been focused on the SPECULOOS Project (Search for habitable Planets EClipsing ULtra-cOOl Stars), which aims to hunt for transits in approximately 1000 of the nearest "ultracool dwarf" stars (UCDs).

The focus of my research has been in developing a pipeline for SPECULOOS which will automate the processes of data reduction and calibration, measure precise aperture photometry, cross-match with various catalogues (e.g. Gaia and 2MASS) and generate light-curves for each star in a field of view. We will then automatically detrend these light curves, perform transit searches and validate (through cross-matching, vetting and follow up observations) the best candidate exoplanets. This pipeline also grants us the ability to perform globalised photometry and globalised analysis of light curves, by combining observational data over several nights in order to analyze the variability of our targets and transits.

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Detecting Young Exoplanets: An Infrared Radial Velocity Survey of T Tauri Stars

Observing and characterizing newly-formed planets around young stars is important for developing planet formation and evolution theory. However, given challenges in detecting young planetary systems, current models are primarily based on systems that are billions of years old. It is therefore unclear which exoplanetary properties are indicators of formation conditions, or of later evolution. We are conducting an infrared radial velocity (RV) survey to detect and confirm young exoplanets around T Tauri stars using the Immersion Grating Infrared Spectrograph (IGRINS) on the 4.3-m Lowell Observatory Discovery Channel Telescope (DCT). IGRINS simultaneously observes H- and K-bands at a resolution of ~45,000. The IGRINS + DCT system is less sensitive than optical systems to RV variability triggered by starspots on active young stars. Our sample consists of ~130 T Tauri stars of age ~1-5 Myr in the relatively nearby Taurus star forming region. We aim to 1) detect and confirm young exoplanets; 2) compare hot Jupiter occurrence rates for pre-main sequence stars to those of main sequence stars; 3) investigate interactions between a circumstellar disk and planets; 4) extend these results to planet formation theory. We report early results on our search for RV variability of T Tauri stars, indicative of the presence of hot Jupiters with the IGRINS + DCT system, with a focus on follow-up of young planet candidate host stars.

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Wolf 503b: A 2 Earth Radius Planet Orbiting a Bright, Nearby K-dwarf

Wolf 503b is a newly found 2.03(+0.08 -0.07) Râ¨• planet orbiting the bright (J=8.32 mag), nearby (D=44.5 pc) high proper motion K3.5V star Wolf 503. The brightness of the host star makes Wolf 503b a prime target for radial velocity follow-up, HST transit spectroscopy, as well as detailed atmospheric characterization with JWST. Using both archival images and high-contrast adaptive optics images from the Palomar observatory, the possibility of a false positive detection due to a companion or background star has been determined to be extremely low. With its measured radius near the gap (from 1.5-2.0 Râ¨•) in the planet radius and occurrence rate distribution, Wolf 503b offers a key opportunity to better understand the origin of this radius gap as well as the nature of the intriguing populations of "super-Earths" and "sub-Neptunes" as a whole.

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The SAINT-EX project: Searching for terrestrial planets around ultra-cool stars

In this contribution, we present the current status of the SAINT-EX (Searching And characterisINg Transiting EXoplanets) project that arises from the collaboration between the SAINT-EX Consortium and the Universidad Nacional AutÃ³noma de MÃ©xico (UNAM). This venture has two main science objectives: i) To search for terrestrial planets orbiting ultra-cool stars, similar to the TRAPPIST-1 system, ii) To give ground-based support for the ESA CHEOPS space mission.

In order to achieve these goals, a fully robotic facility hosting a 1-m telescope is to be installed at the National Astronomical Observatory of MÃ©xico, in San Pedro MÃ¡rtir. The facility's first light is foreseen in Summer 2018 and will be used to perform a photometric follow-up of Northern Hemisphere stars in the search for signals of planetary transits.

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Dark Hole Maintenance and A Posteriori Intensity Estimation in Presence of Speckles Drift

Direct exoplanet imaging via coronagraphy requires maintaining high contrasts in the dark hole for lengthy integration periods. Wavefront errors that change slowly over that time, accumulate and cause systematic errors in star's Point Spread Function (PSF) which limits the signal to noise ratio of the planet. We suggest that estimating the above speckles drift can be achieved via intensity measurements in the dark hole together with dithering of the deformable mirrors to increase phase diversity. A scheme based on Extended Kalman Filter and Electric Field Conjugation is proposed for maintaining the dark hole during the integration phase. For the post processing phase, an a posteriori approach is proposed to estimate the realization of the PSF drift process and the intensity of the light incoherent with the speckles.

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Comparison of BT Settl Model Spectra in NIR to Brown Dwarfs and Massive Exoplanets

Our understanding of giant exoplanets and brown dwarfs is hampered by the difficulty in observing them. Model spectra, such as the BT Settl model grid, can provide an opportunity to augment and validate our understanding of these faint objects by serving to contrast and complement our analysis of the observed spectra. The near infrared (NIR) K band wavelength region (1.97 - 2.40 microns) is favorable for analysis of low mass brown brown dwarfs and high mass gaseous companions due to its relatively high resolution and high signal-to-noise ratio wavelength range for spectra of planetary companions. We present a method to analyze the K band spectral structure and apply it to a sample of objects with field gravity, low gravity, and planetary mass as well as the BT Settl model grid for a similar range of effective temperatures and surface gravities. A correlation between spectral structure and effective temperature is found for the shorter wavelength region (2.03 - 2.10 microns), and there is evidence of gravity dependence for the longer wavelength range (2.215 - 2.290 microns). This work suggests that the K band has the potential to be an indicator for brown dwarf and exoplanet surface gravity and effective temperature. We also present analysis of the BT Settl Model grid examining equivalent width measurements of K I absorption lines in L Dwarfs.

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Nature vs. Nurture: A Statistical Framework for Assessing Posited Correlations between Stellar Age and Planetary Orbital Properties

Some planetary systems appear to exhibit a trend between certain orbital characteristics -- such as spin-orbit misalignment, the presence of 2:1 resonances, and orbital eccentricity -- and the age of the system. However, a starâ€™s age is also related to other properties such as stellar mass and temperature that may correlate with different orbital evolution histories. Therefore it can be ambiguous whether such trends are actually due to planetary orbital evolution or other parameters that affect instead the initial conditions of the system. The situation is complicated further by the possibilities of selection biases, small number statistics, uncertainties in stellar age, and orbital evolution timescales that are typically much shorter than the range of observed ages.

We are working to assess the robustness of observed correlations and to determine whether they are indeed due to evolutionary processes, or if they more likely reflect different formation scenarios. Using the specific cases mentioned above as a guide, we are working to develop a Bayesian statistical framework for this assessment that can then be applied more generally.

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A Near-Infrared Search for Transiting Exoplanets around Brown Dwarfs using the 1.8-m Perkins Telescope

Transiting exoplanets in the habitable zone around brown dwarfs will be some of the most favorable habitable targets for follow-up atmospheric characterization with JWST, owing to large transit depths. However, we currently know of no transiting exoplanets around brown dwarfs, despite recent observing efforts to target later spectral types (e.g., MEarth). We present plans for a multi-year search for transiting exoplanets around brown dwarfs, using the Mimir instrument on the 1.8-m Perkins Telescope in Flagstaff, AZ. Through transit injection/recovery tests with Mimir photometry, and by simulating our survey with known M-dwarf occurrence rates, we predict the discovery of a handful of planets over the course of the 5 year survey. We present our planned observing strategy, and the simulation tool that we are developing to predict our surveyâ€™s planet yield. We also show some preliminary brown dwarf lightcurves taken in J-band with Mimir to demonstrate our ability to slew between different targets on a single night of observing.

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Space-Like Infrared Photometry and Spectroscopy of Transiting Exoplanets with WIRC

The precision of ground-based measurements of transiting exoplanets is typically limited by time-correlated noise from telescope pointing variations and changes in the shape of the point spread function. We effectively mitigate these issues by implementing sub-pixel level guiding and utilizing an engineered diffuser to control the shape of the point spread function for observations taken with the Wide-field InfraRed Camera (WIRC) on the Hale 200â€• telescope. Here we present some applications of WIRC for exoplanetary science, including measurements of transit timing variations with diffuser-assisted photometry and preliminary atmospheric characterization using R~100 multi-object slitless spectroscopy.

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Stellar Magnetic Activity Indicators

Starspots, plages, and activity cycles cause radial velocity variations that can either mimic planets or hide their existence. To verify the authenticity of newly discovered planets, observers may search for periodicity in spectroscopic activity indices such as Ca H & K and H â•º, then mask out any Doppler signals that match the activity period or its harmonics. However, not every spectrograph includes Ca H & K, and redder activity indicators are needed for planet searches around low-mass stars. Here we show how new activity indicators can be identified by correlating spectral line depths with a well-known activity index. We apply our correlation methods to archival HARPS spectra of Îµ Eri and â•º Cen B and use the results from both stars to generate a master list of activity-sensitive lines whose core fluxes are periodic at the star's rotation period. Our newly discovered activity indicators can in turn be used as benchmarks to extend the list of known activity-sensitive lines toward the infrared or UV. With recent improvements in spectrograph illumination stabilization, wavelength calibration, and telluric correction, stellar activity is now the biggest noise source in planet searches. Our suite of > 40 activity-sensitive lines is a first step toward allowing planet hunters to access all the information about spots, plages, and activity cycles contained in each spectrum.

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Using Ground-Based Surveys to Precover TESS Single Transits.

Due to the mission configuration, in 74% of the observed area, TESS can only capture one or two transits for planets with orbital periods longer than 13.5 days, which means the true ephemerides will be difficult to determine from TESS data alone. The Kilodegree Extremely Little Transit (KELT) survey has a long observation baseline and monitors fields that largely overlap with the TESS footprint, and also observes stars of similar brightness. We insert simulated TESS-detected single transits into KELT light curves, and find that KELT photometry can be used to confirm ephemerides with high accuracy for planets of Saturn size or larger with orbital periods as long as a year, and therefore span a wide range of planet equilibrium temperatures. In a large fraction of the sky our average recovery rate can be as high as 40%. The resulting periods and ephemerides of the signals can then be used by follow-up teams, to plan and coordinate follow-up observations to confirm candidates as planets, eclipsing binaries, or other false positives, as well as to conduct detailed transit observations with facilities like JWST or HST.

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Debris Disk Characterization Using Alternate IR Photometries From 2MASS

To characterize debris disks, we must obtain good photometry in order to accurately fit stellar photosphere models for the host stars. For nearby bright stars, particularly those with K magnitude less than 5, obtaining good near-IR photometry with 2MASS is difficult because of issues with saturation. This is particularly a problem for debris disk detection and characterization because for those tasks, we rely on measuring photometric excesses on the Rayleigh-Jeans tail of the spectra, which 2MASS constrains. To accurately characterize debris disks detected with Spitzer, Herschel, WISE, and even the eventual JWST, we use alternative sources for IR photometry in order to avoid the use of saturated 2MASS photometry. In particular, we use NASA Catalog of Infrared Observations for IRJK photometry. For many stars, JK photometry is unavailable, but we nonetheless try to fill the gap with available IR and W1 (saturation corrected) photometries. Our goal is to obtain new photosphere models and re-analyze infrared excess detections for nearby, bright stars whose debris disks subtend large angles on the sky, making them suitable for resolved JWST imaging.

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Debris Disks in L'-band with the Vortex Coronagraph

I will present lessons learned from observing disks with the Vortex coronagraph on Keck-NIRC2.

Norbert Zicher (norbert.zicher@physics.ox.ac.uk)

Spectroscopic Variability in M50 & analysis of Au Mic

Analysis of Messier 50 from the Monitor Project in order to identify binaries, model stellar variability together with building and testing a Gaussian Process approach for better radial velocity extraction.
Stellar activity modelling for Au Mic using a Gaussian Process Framework together with radial velocity extraction in order to improve on current results.