Extreme Precision in Radial Velocity IV

Report of Contributions

https://indico.global/e/9078

Contribution ID: **7** Type: **Oral**

Reconciling the planetary interpretation of the radial velocity super-Earth K2-18c

Monday 18 March 2019 11:20 (20 minutes)

The nearby mid-M dwarf K2-18 hosts a known transiting super-Earth. The so-called K2-18b orbits close to the inner edge of the habitable zone making it an interesting target for future atmospheric characterization of an M dwarf planet receiving Earth-like insolation. In 2017, the HARPS follow-up campaign to characterize the mass of K2-18b revealed a strong periodic signal at ~ 9 days that was shown to likely be due to a second, non-transiting super-Earth (K2-18c) located interior to orbit of K2-18b. However, independent CARMENES observations of this system in 2018 revealed a significantly weaker 9-day signal and claimed that its origin is more likely related to stellar activity because of the signal strength's apparent chromatic and temporal variability. I will present results from the continued HARPS monitoring of K2-18 and our self-consistent modelling efforts of the joint HARPS plus CARMENES data aimed at reconciling the nature of the 9-day signal. We conclude that the chromatic and temporal variations in the periodic signal strength is consistent with a planetary signal modulated by changing levels of stellar activity. We also conclude that the disparate results from HARPS and CARMENES are likely due to sub-optimal time-sampling in the CARMENES window function which appears to artificially suppress the K2-18c periodicity. This work highlights the importance of understanding one's time-sampling and the importance of probabilistic modelling of planets and stochastic activity, particularly when searching for sub-Neptune-sized planets with radial velocities.

Author: Mr CLOUTIER, Ryan

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Presenter: Mr CLOUTIER, Ryan

Session Classification: Stellar signal 2

Track Classification: Stellar signals

Contribution ID: **8** Type: **Oral**

FIESTA: new technique to parametrize stellar variability

Monday 18 March 2019 11:40 (20 minutes)

We've been developping a new technique - FourIEr *phase* SpecTrum Analysis (ESTA or FIESTA) - that studies the spectral line profile variability in the Fourier space. It enables us to distinguish a line deformation from a line shift and provides the possibility to correct jitter. I will briefly lay out the theories and demonstrate its application in two example stars: (1) HD189733: Rossiter–McLaughlin effect as jitter; (2) α Centauri B.

Author: ZHAO, Jinglin (UNSW)

Co-author: Prof. TINNEY, Chris (UNSW)

Presenter: ZHAO, Jinglin (UNSW)

Session Classification: Stellar signal 2

Track Classification: Stellar signals

Contribution ID: **11** Type: **Oral**

First results from PEPSI

Wednesday 20 March 2019 09:15 (15 minutes)

We present recent results from the latest addition to the spectrograph zoo: PEPSI, the new bench-mounted fiber-fed and stabilized "Potsdam Echelle Polarimetric and Spectroscopic Instrument"for the 11.8m Large Binocular Telescope (LBT). Besides the LBT the instrument is also fiber linked to a disk-integration solar telescope and the Vatican Observatory's 1.8m VATT. I will introduce PEPSI and focus on first data and results in order to "feel the taste". Among the first targets were the Sun and solar twins, Gaia benchmark stars, Jupiter's Io, planet-host stars with hot Jupiters as well as stars with Earth-sized planets, novae, the ISM, and much more.

Author: Prof. STRASSMEIER, Klaus (AIP)

Co-author: AND THE PEPSI TEAM

Presenter: Prof. STRASSMEIER, Klaus (AIP)

Session Classification: VIS instruments

Track Classification: Instruments in VIS

Contribution ID: **13** Type: **Oral**

The Veloce Doppler Spectrograph at the AAT

Wednesday 20 March 2019 09:00 (15 minutes)

Veloce is a new precision Doppler spectrograph for the 3.9m Anglo-Australian Telescope sited on Siding Spring Observatory in Australia. Cost considerations for an instrument with a total budget of A$5.4m mean that *Veloce's* design philosophy is one of "just enough" stabilisation (i.e. stabilising the spectrograph in pressure and temperature so that changes over time will be small and linear) combined with simultaneous calibration in every exposure. It uses a fibre-optic integral-field unit to reformat a 2.5" aperture into a 19 fibre x 0.5" slit at the spectrograph entrance, plus 5 sky fibres and two fibres for simultaneous calibration using either a ThXe arc lamp, or a Menlo Systemsastro comb (delivered directly into the spectrograph by an endlessly single-mode fibre). The main fibre run comprises octagonal fibres passing through two fibre agitators, which are then fused to circular fibres before injection into the spectrograph. The spectrograph's first *Rosso* camera covers 600-930nm, with two additional cameras (*Verde* and *Azzurro*) funded for installation in 2019 to provide complete coverage from 380-930nm in a single exposure. The optical performance of the *Rosso* camera (which started operation in September) is excellent, with the average FWHM of images from the singe-mode astrocomb being less than 1 pixel over the whole echellogram. While processing the IFU data has provided challenges, early results are very promising, and by EPRV IV I hope to be able to highlight recent TESS mass measurement results from *Veloce*.

Authors: Prof. TINNEY, Chris (UNSW Sydney); BERGMANN, Christoph (UNSW Sydney); Dr IRELAND, Michael (ANU); Dr GILBERT, James (Australian National University); Dr WRIGHT, Duncan (USQ); Dr SCHWAB, Christian (Macquarie University)

Presenter: Prof. TINNEY, Chris (UNSW Sydney)

Session Classification: VIS instruments

Track Classification: Instruments in VIS

Contribution ID: **15** Type: **Poster**

RadVel: The Radial Velocity Fitting Toolkit, its applications to transiting planet characterization, and to blind searches in RV data

We show how to use the Python package RadVel to characterize Keplerian orbits of planetary systems with radial velocity (RV) data. RadVel can model multi-planet, multi-instrument datasets, while incorporating constraints such as transit ephemerides and secondary eclipse times. It includes several built-in Gaussian process kernels for the treatment of stellar activity, and employs MCMC and Bayesian modeling techniques to precisely determine the posterior distributions of planetary properties. We show how to use RadVel in conjunction with RV, Kepler, and K2 data, to better characterize the masses and orbits of transiting planets. We also introduce an associated software package, RVSearch, which is currently under development and can be used for blind RV planet detection in conjunction with RadVel. RVSearch combines the Bayesian methods and Keplerian fitting tools of RadVel with a periodogram-based algorithm to search for planets in RV datasets, iteratively accepting potential planetary signals until they fail to surpass an empirically calculated threshold for goodness-of-fit. To learn more about RadVel and RVSearch, visit radvel.readthedocs.io.

Author: ROSENTHAL, Lee (California Institute of Technology)

Co-authors: HOWARD, Andrew (California Institute of Technology); PETIGURA, Erik (California Institute of Technology); MILLS, Sean (California Institute of Technology); FULTON, Benjamin (California Institute of Technology); BLUNT, Sarah (Harvard University); SINUKOFF, Evan (California Institute of Technology)

Presenter: ROSENTHAL, Lee (California Institute of Technology)

Track Classification: Computational and statistical methods

Contribution ID: **16** Type: **Oral**

Diffraction-Limited Instruments for PRV Measurements and Direct Planet Spectroscopy

Tuesday 19 March 2019 17:45 (20 minutes)

Advances in Adaptive Optics have made it possible to develop a new generation of very high spectral resolution spectrometers R˜(100,000-150,000) operating in the deep red and near-IR on large telescopes. These instruments can be used both for precision radial velocity (PRV) measurements when coupled with high precision calibration sources, direct spectroscopy of exoplanets, as well as for a number of general astrophysics science cases.
Feeding a diffraction-limited beam into a single mode fiber has many advantages: the small A*Omega of a diffraction-limited beam enables a much more compact instrument than a seeing-limited one; a compact instrument is easier to maintain under precise thermal control for high opto-mechanical stability; the use of single mode fibers eliminates mode scrambling and many PRV error budget terms related to instrument point spread function and telescope pointing; and finally a compact instrument is inherently lower cost than a seeing-limited one.
We are presently integrating a prototype PRV instrument, Palomar Advanced Radial Velocity Instrument (PARVI), for the Palomar 5-m telescope, and designing another PRV instrument, HISPEC, for Keck, to be pathfinders for diffraction-limited spectrographs on future ELTs, like TMT. We will discuss science programs for PARVI and HISPEC as well as the design and development status of both instruments. Finally, we note that on a space-based telescope such as the EarthFinder it would be possible to extend these benefits into visible wavelengths.

Authors: BEICHMAN, Chas; MAWET, Dimitri (Caltech); VASISHT, Gautam (JPL); LEIFER, Stephanie (JPL); NILSSON, Ricky (Caltech); FUCIK, Jason (Caltech); MICHAEL, Fitzgerald (UCLA); JOVANOVIC , Nemanja

Presenter: BEICHMAN, Chas

Session Classification: Optical challenges

Track Classification: Instrument and calibration challenges

Contribution ID: **19** Type: **Oral**

IRD: Infrared PRV instrument for the Subaru Telescope

Wednesday 20 March 2019 10:30 (15 minutes)

The Infrared Doppler (**IRD**) instrument is a fiber-fed high-resolution near-infrared spectrometer for the Subaru 8.2-m telescope covering the Y-, J-, and H-bands simultaneously with a spectral resolution of ~70,000. It aims at achieving measurement precision of 1-2 m/s in radial velocity (RV) with a very stable spectrograph and an original laser frequency comb. The most effective astronomical targets of IRD are M dwarfs, especially late-M dwarfs, which are too faint to observe at optical wavelengths even with such a large telescope. IRD's commissioning at the summit started in March 2017 and first light observations were successfully carried out in August 2017. A Subaru Strategic Program (SSP) survey has started from 2019A. We report the current status of the instrument and the planned survey.

Author: Dr KOTANI, Takayuki (ABC/NAOJ)

Co-authors: Prof. TAMURA, Motohide (UTokyo/ABC/NAOJ); IRD TEAM

Presenter: Dr KOTANI, Takayuki (ABC/NAOJ)

Session Classification: NIR instruments

Track Classification: Instruments in nIR

Contribution ID: **20** Type: **Oral**

Gaussian processes regression networks for the analysis of RV data

Tuesday 19 March 2019 11:30 (20 minutes)

Since the discovery of the first extra-solar planet in 1995, Doppler spectroscopy proved to be one of the most successful methods in the search of exoplanets. With new high precision instruments like ESPRESSO and new data analysis methods, it will be possible to detect Earth-like planets on Sun-like stars with similar orbital parameters of Earth. Unfortunately, the search for exoplanets comes with several challenges. Stellar noise usually contaminates the RV measurements, due to the intrinsic activity star, that can hide or mimic planetary signals. Besides this problem, it is also difficult to ascertain the real number of planetary signals present in the data.
To deal with these two issues it was developed a tool called kima. This freely available software combines an MCMC algorithm known as diffusive nested sampling with Gaussian processes (GP) to model the stellar component of the signal and infer the number and properties of the existing planetary signals.
A new version of kima is being developed combining the previous MCMC algorithm with a Gaussian processes regression network (GPRN) that combines the properties of a Bayesian neural network with the flexibility of the GPs. The novelty of this regression network comes with its ability to take into account multiple inputs such as RV, bisector inverse slope, full width half maximum and activity indicators, e.g. log(R_hk).
This GPRN will be an adaptive mixture of GPs that accommodates the signal and noise correlations from various output variables. It will allow the full characterization of the stellar activity in a set of RV measurements and disentangle planetary signals, stellar activity, telluric contamination, and instrumental noise from the stellar spectra, bringing us ever closer to the
detection of Earth-like planets in the habitable zone of Sun-like stars.

Author: CAMACHO, João (Instituto de Astrofísica e Ciências do Espaço)

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Presenter: CAMACHO, João (Instituto de Astrofísica e Ciências do Espaço)

Session Classification: Computational and statistical challenges

Track Classification: Computational and statistical methods

Contribution ID: **21** Type: **Poster**

Photon limits of radial velocity precision for VIS and NIR instruments

Spectroscopic information content and stellar brightness define the fundamental limits for radial velocity (RV) measurements. We summarize the available theoretical and empirical information about RV precision limits and compare the performance between various VIS and NIR instrument designs.

Author: REINERS, Ansgar (Georg-August Universität Göttingen)

Co-author: ZECHMEISTER, Mathias (Georg-August Universität Göttingen)

Presenter: REINERS, Ansgar (Georg-August Universität Göttingen)

Track Classification: Error budget in EPRV

Contribution ID: **23** Type: **Oral**

Robustness of eccentricity estimates

Tuesday 19 March 2019 11:50 (20 minutes)

The eccentricity of a planet is a key information on its present dynamics and puts constraints on formation scenarios. However, eccentricity estimates are known to be subject to caution, for instance it has been shown that low eccentricities are on average overestimated. In this talk, we present a comprehensive study of the eccentricity estimation from radial velocity data and give conditions for robust inference. We address in particular whether the estimates can be trusted even if the model used for the data analysis is incorrect. By that we mean that the data contains unmodelled stellar noises, missed planetary companion, poorly chosen priors... We present which types of modelling errors affect most the eccentricity estimates, and also discuss the numerical errors effects. We suggest data analysis methods to determine if the eccentricity of a planet is to be trusted or if it is an artefact of an inappropriate modelling.

Author: Mr HARA, Nathan (Université de Genève)

Co-authors: Dr BOUÉ, Gwenaël (Observatoire de Paris); Prof. LASKAR, Jacques (Observatoire de Paris); Dr DELISLE, Jean-Baptiste (Observatoire de Genève)

Presenter: Mr HARA, Nathan (Université de Genève)

Session Classification: Computational and statistical challenges

Track Classification: Computational and statistical methods

Contribution ID: **24** Type: **Oral**

HARPS-N radial velocities from the Sun-as-a-star

Monday 18 March 2019 09:50 (20 minutes)

Distinguishing between a signal induced by stellar activity or a planet is the main challenge in radial velocity (RV) searches for low-mass exoplanets these days. Even when the presence of a transiting planet and hence its period are known, stellar activity is often the main barrier in nailing down the correct amplitude of the planetary signal. Observing the Sun-as-a-star provides a unique test case to probe activity-related signals in RV data. I will present the first results of three years of HARPS-N data of the Sun-as-a-star.
In this talk, I will take you through the different steps of automatic data processing needed to be able to treat the Sun as a star. I will show the significant signals we find from granulation on a daily basis and solar activity on longer timescales. By using stacked periodograms, the highly variable nature of the solar RV data can be be presented. I will show you how line-shape variability clearly correlates with the RVs, but with a time delay.

Author: MORTIER, Annelies (University of Cambridge)

Presenter: MORTIER, Annelies (University of Cambridge)

Session Classification: Stellar signals 1

Track Classification: Stellar signals

Contribution ID: **25** Type: **Poster**

Keck Planet Finder

KPF is a fiber-fed, high-resolution, high-stability spectrometer in development for the W.M. Keck Observatory. The instrument is designed to characterize exoplanets via Doppler spectroscopy with a single measurement precision of 0.5 m/s or better, however its resolution and stability will enable a wide variety of other astrophysical observations. KPF will have a resolving power of > 80,000, with the bandpass spanning a green channel (445 nm to 600 nm) and a red channel (600 nm to 870 nm). A novel design aspect of KPF is the use of a Zerodur optical bench, and Zerodur optics with integral mounts, to thermally and mechanically stabilize the spectrometer. The KPF project has passed its preliminary design review and is currently in the detailed design phase, and here we will focus on engineering aspects and the overall design of the instrument.

Author: Dr GIBSON, Steven (UC Berkeley)

Co-authors: Dr HOWARD, Andrew (Caltech); Dr ROY, Arpita (Caltech); Mr SMITH, Christopher (UC Berkeley); Dr HALVERSON, Sam (MIT); Dr EDELSTEIN, Jerry (UC Berkeley); Dr KASSIS, Marc (W.M. Keck Observatory); Mr RIDER, Kodi (UC Berkeley); Dr WISHNOW, Edward (UC Berkeley)

Presenter: Dr GIBSON, Steven (UC Berkeley)

Track Classification: Instruments in VIS

Contribution ID: **26** Type: **Poster**

The NIRSPEC Upgrade for the Keck II Telescope

NIRSPEC is a high-resolution (R=□/□□˜25,000), cross-dispersed, echelle spectrograph operating from 1-5 um on the Keck II telescope. In Fall 2018, we upgraded the instrument to increase its sensitivity and ensure its continued longevity. We have also used the NIRSPEC instrument as a testbed for developing new technologies, such as laser frequency combs, to improve instrumental stability for upcoming extreme precision radial velocity (PRV) instruments. We present details on the major components of the upgrade, including 1) new spectrometer detector, 2) new slit viewing camera, 3) new motion control electronics, and 4) improved instrumental stability. We will show initial on-sky results from our December 2018 commissioning and discuss the impact the upgrade will have for observers. The improvements we are making will increase sensitivity in the photon-limited regime by ˜1 mag, allowing for observations of fainter targets and more efficient observing. We also expect the stability improvements to improve our sensitivity below ˜100 m/s. We will discuss these improvements in the context of upcoming PRV instruments, with lessons-learned.

Author: Dr MARTIN, Emily (UCSC)

Co-authors: Prof. FITZGERALD, Michael (UCLA); Dr DOPPMANN, Gregory (Keck Observatory); Dr KASSIS, Marc (Keck Observatory); Prof. MCLEAN, Ian (UCLA); Mr ALIADO, Ted (UCLA); Mr CANFIELD, John (UCLA); Mr JOHNSON, Chris (UCLA); Mr KRESS, Evan (UCLA); Mr LANCLOS, Kyle (Keck Observatory); Mr MAGNONE, Ken (UCLA); Mr SOHN, Ji Man (UCLA); Mr WANG, Eric (UCLA); Mr WEISS, Jason (UCLA); Dr WILCOX, Mavourneen (Keck Observatory)

Presenter: Dr MARTIN, Emily (UCSC)

Track Classification: Instruments in nIR

Contribution ID: **27** Type: **Oral**

Using Gaussian processes for precise and robust radial velocity extraction

Thursday 21 March 2019 12:10 (20 minutes)

Thanks to a number of technical developments, the precision of RV surveys has been steadily improving. While the spectrographs of fifty years ago yielded RVs with errors in excess of 1 km/s, today's state-of-the-art stabilised spectrographs boast 10 cm/s precisions. Yet very little has changed in the way individual RVs are actually extracted from observed spectra: i.e., cross correlating observed spectra with a weighted template. This approach suffers a few notable drawbacks, including that

1. a given template will generally be an imperfect match to any observed star's spectrum;
2. information is discarded when computing RVs;
3. the RV extraction process is sensitive to stellar activity variability and telluric contamination; and
4. acquiring more spectra does not improve the accuracy or precision of existing RVs, despite the additional spectra containing potentially-useful new constraints.

I'll present a new data-driven approach for extracting RVs that aims to address these drawbacks. The new method models each spectrum in an ensemble of spectra with a Gaussian process (GP), then aligns each GP model with every other GP model spectrum. In so doing, the method effectively builds up a super-resolved, low-noise template spectrum, and is incidentally also able to yield RVs that are less sensitive to stellar activity and telluric contamination than RVs extracted with more conventional approaches.

This new method is conceptually simple, and its performance very favourable using both synthetic and real data. As such, it has the potential to enable the study of smaller planets around a wider variety of stars than has previously been possible. It could also be fruitfully applied to archival data.

Author: Dr MAGUIRE-RAJPAUL, Vinesh (University of Cambridge)

Co-authors: Prof. AIGRAIN, Suzanne (University of Oxford); Prof. BUCHHAVE, Lars (Technical University of Denmark)

Presenter: Dr MAGUIRE-RAJPAUL, Vinesh (University of Cambridge)

Session Classification: From raw spectra to EPRV: RV pipeline

Track Classification: From raw spectra to EPRV: RV pipelines

Contribution ID: **28** Type: **Poster**

Development and Characterization of an Ultra Stable Single Mode Fiber Fed Spectrograph in the Infrared

To deliver a radial velocity instrument capable of extreme precision requires careful design with attention to the interplay of optical, mechanical and thermal design choices. Ideally, an instrument starts with a spectrograph of sufficient resolution and an intrinsic stability that leads to optimal precision over months or years. For a demonstrator instrument developed at Macquarie University, we trade off optical and mechanical design choices, and use advances in photonic technologies as enablers to satisfy science cases requiring extreme precision. We start at the fiber injection with single mode fibers to feed the spectrograph, thus eliminating issues with modal noise in the beam. Our design also allows for the use of a diffraction-limited integral field unit to take spatially resolved spectra of stellar surfaces. In this case, microlens arrays on seven single mode fiber cores are arranged in a hexagonal patterned multicore fiber. The spectrograph itself is a white pupil design utilizing a monolithic 152 mm primary mirror with 550 mm focal length. The dispersive element is a 60 mm x 150 mm silver coated Zerodur R6 grating from Richardson Grating Labs. The groove count is sufficiently low at 13.33 lines/mm to keep the orders narrow, allowing for the use of an InGaAs detector with limited pixel count. We design mounts for all the elements on the bench, analyse the stresses and displacements with finite element analysis and machine them from Al-6061. With the spectrograph taking shape in the lab, we measured the grating efficiency and spot qualities to verify our design and as-built specifications. We use a volume phase holographic grating as a cross disperser and custom camera optics to feed the InGaAs detector. The detector comes from Princeton Infrared Technologies, and has a peak quantum efficiency >80 % at 1200 to 1600 nm, covering the near infrared part of the design spectral range of 650 to 1500 nm. The detector has 12 micron pixels and at 1280x1024 offers us a comparatively large format for the cost. We also evaluate the detector, measure it's noise levels, and write control software to make it suitable for astronomical observations.

Authors: KUO TIONG, Blaise (Macquarie University); Dr SCHWAB, Christian (Macquarie University); Dr FEGER, Tobias (Macquarie University); Mr ANAGNOS, Theodoros (International Max Planck Research School for Astronomy & Cosmic Physics at the University of Heidelberg); Prof. COUTTS, David (Macquarie University)

Presenter: KUO TIONG, Blaise (Macquarie University)

Track Classification: Instruments in nIR

Contribution ID: **29** Type: **Poster**

The NEID Spectrometer CCD System

Detecting Earth-mass exoplanets using the Doppler method places stringent requirements on detector stability. NEID is a new Doppler spectrometer in development for the WIYN 3.5-m telescope at Kitt Peak National Observatory as part of the NN-Explore partnership. The wide spectral grasp of NEID (380-930 nm) requires a monolithic CCD detector with a large area, small pixels, and excellent quantum efficiency across the NEID bandpass. NEID employs a single, deep depletion CCD290-99 device from e2v having 9Kx9K pixels with 10-micron pitch and Astro Multi-2 AR coating. We describe the results of a detector characterization effort ongoing at the University of Pennsylvania. We present measurements of the thermal variation of the detector package during operation and a promising clocking-based method for reducing the amplitude of these thermal variations to the mK level.

Authors: BLAKE, Cullen (University of Pennsylvania); Dr LI, Dan (NOAO); Dr TUFTS, Jospeh (STA, Inc.); Prof. MAHADEVAN, Suvrath (Penn State University); Dr HEARTY, Fred (Penn State University); Dr MONSON, Andrew (Penn State University); Dr ROY, Arpita (California Institute of Technology); Dr HALVERSON, Samuel (MIT); Prof. TERRIEN, Ryan (Carleton College); Mr STEFANSSON, Gudmundur (Penn State University); Prof. SCHWAB, Christian (Macquarie University); Dr NINAN, Joe (Penn State University); Dr BENDER, Chad (Steward Observatory); Dr MCELWAIN, Michael (NASA)

Presenter: BLAKE, Cullen (University of Pennsylvania)

Track Classification: Instrument and calibration challenges

Contribution ID: **30** Type: **Poster**

MINERVA-Red

The discoveries of the Earth-sized exoplanets orbiting Proxima Centauri and Trappist-1 lend further support to the theory that terrestrial planets may be common around low-mass stars. Since low-mass stars are intrinsically faint at optical wavelengths, obtaining the meter-per-second Doppler precision necessary to detect their Earth-sized planetary companions remain a challenge for instruments designed to observe Sun-like stars. To study these "redder"stars, new spectrometers must be developed. We describe the MINERVA-Red spectrometer and a novel, ultra-high-cadence observing approach aimed at detecting and characterizing planets orbiting the closest low-mass stars to the Sun. In order to characterize the impact of astrophysical noise on our radial velocity measurements, we will gather simultaneous photometry (ugriz, Halpha, Hbeta, Calcium H&K), which will provide a substantial dataset for studying the short-term line and continuum photometric variability in cool stars. We will present photometric results from this robotic observatory and the current status of the spectrograph.

Authors: Prof. BLAKE, Cullen (University of Pennsylvania); Mr SLISKI, David (University of Pennsylvania); Dr HALVERSO, Samuel (MIT); Dr EASTMAN, Jason (Harvard Smithsonian Center for Astrophysics); Ms BAKER, Ashley (University of Pennsylvania); Prof. JOHNSON, John (Harvard University); Prof. WITTENMYER, Rob (University of Southern Queensland)

Presenter: Mr SLISKI, David (University of Pennsylvania)

Track Classification: Instruments in nIR

Contribution ID: **31** Type: **Oral**

MINERVA-Australis and SONG: New PRV Observatories in Australia

Wednesday 20 March 2019 08:45 (15 minutes)

NASA's Transiting Exoplanet Survey Satellite (TESS) will identify thousands of planets orbiting nearby bright stars in a two-year survey beginning in the Southern sky. MINERVA-Australis at USQ's Mount Kent Observatory is the only southern hemisphere precise radial velocity facility wholly dedicated to follow-up of TESS planets. Mass measurements of these planets are critically necessary to maximise the scientific impact of the TESS mission, to understand the composition of exoplanets and the transition between rocky and gaseous worlds. MINERVA-Australis is now operational at the University of Southern Queensland's Mount Kent Observatory, with three of the planned six 0.7m telescopes in place. I present first precise radial velocity results and orbital solutions for TESS planets, and give an update on the performance of MINERVA-Australis.

The Stellar Observations Network Group (SONG) is establishing a node at Mount Kent. SONG-Australia will complete the global longitude coverage, delivering breakthroughs in fundamental understanding of the interiors of stars for decades to come. SONG-Australia is designed on a "MINERVA" model, whereby fibres from multiple small telescopes feed a single high-resolution spectrograph. As a result of these innovations, SONG-Australia is expected to be fully operational by late 2019. I present results from the Tenerife SONG node which is delivering 1 m/s precision velocities.

Authors: Prof. WITTENMYER, Rob (University of Southern Queensland); Dr WRIGHT, Duncan (University of Southern Queensland); Dr BOWLER, Brendan (University of Texas at Austin); Dr CROSSFIELD, Ian (MIT); Dr KANE, Stephen (University of California Riverside); Prof. KIELKOPF, John (University of Louisville); Prof. PLAVCHAN, Peter (George Mason University); Prof. TINNEY, Chris (UNSW Australia); Dr ZHANG, Hui (Nanjing University)

Presenter: Prof. WITTENMYER, Rob (University of Southern Queensland)

Session Classification: VIS instruments

Track Classification: Instruments in VIS

Contribution ID: **32** Type: **Poster**

MINERVA Australis performance and analysis

MINiature Exoplanet Radial Velocity Array (MINERVA) - Australis is a new telescope array and spectrograph at Mt Kent observatory in Australia. It is run by a consortium of US, Australian and Chinese universities and has been operational since 2018 Nov 10. It is made up of five 0.7m CDK 700 telescopes from Planewave (three currently installed and operating) and a high-resolution (R>80000) spectrograph from KiwiSpec covering 480 - 630nm.

The spectrograph is fed with fibres from each telescope, is thermally stabilised, and is calibrated using a simultaneous Thorium-Argon arc-lamp. I will present details of our instrumental setup, thermal stability, instrumental drift and resulting RV performance.

Author: WRIGHT, Duncan (University of Southern Queensland)

Presenter: WRIGHT, Duncan (University of Southern Queensland)

Track Classification: Instruments in VIS

Contribution ID: **34** Type: **Oral**

Unveiling Iodine-Calibrated RV Spectroscopy

Thursday 21 March 2019 11:50 (20 minutes)

An iodine cell placed in the light path of a high-resolution spectrograph can act as a simultaneous wavelength and point-spread-function fiducial which enables precise radial velocities to be extracted from un-stabilized or slit-fed spectrographs. This technique enabled the detection and characterization of many of the first known exoplanets and played a significant role in establishing the study of exoplanets as a subfield of astronomy. However, the pipelines needed to extract precise velocities from the data are extremely complex and generally treated as a "black boxes" for many end users. I will explain the methodology of the iodine technique in detail and unveil some aspects often pushed under the rug. I will show some of the sources of systematic noise present in the final velocities and describe potential avenues for the removal of these systematics from the vast library of archival data. I will discuss some of the limitations inherent to the technique, paths to improve iodine-based instrumentation, and the role of iodine RV spectroscopy in the future.

Author: FULTON, Benjamin (California Institute of Technology)

Co-author: ISAACSON, Howard (UC Berkeley)

Presenter: FULTON, Benjamin (California Institute of Technology)

Session Classification: From raw spectra to EPRV: RV pipeline

Track Classification: From raw spectra to EPRV: RV pipelines

Contribution ID: **35** Type: **Oral**

Data-Driven Spectroscopy of Cool Stars at High Spectral Resolution

Tuesday 19 March 2019 12:10 (20 minutes)

The advent of large-scale spectroscopic surveys underscores the need to develop robust techniques for determining stellar properties ("labels", i.e., physical parameters and elemental abundances). However, traditional spectroscopic methods that utilize stellar models struggle to reproduce cool (<4700 K) stellar atmospheres due to an abundance of unconstrained molecular transitions, making modeling via synthetic spectral libraries difficult. Because small, cool stars such as K and M dwarfs are both common and good targets for finding small, cool planets, establishing precise spectral modeling techniques for these stars is of high priority. To address this, we apply The Cannon, a data-driven method of determining stellar labels, to Keck High Resolution Echelle Spectrometer (HIRES) spectra of 141 cool (<5200 K) stars from the California Planet Search. Our implementation is capable of predicting labels for small (<1 R⊠) stars of spectral types K and later with accuracies of 68 K in effective temperature (Teff), 5% in stellar radius (R∗), and 0.08 dex in bulk metallicity ([Fe/H]), and maintains this performance at low spectral resolutions (R < 5000). As M-dwarfs are the focus of many future planet-detection surveys, this work can aid efforts to better characterize the cool star population and uncover correlations between cool star abundances and planet occurrence for constraining planet formation theories.

Authors: BEHMARD, Aida (Caltech); PETIGURA, Erik (California Institute of Technology); HOWARD, Andrew (California Institute of Technology)

Presenter: BEHMARD, Aida (Caltech)

Session Classification: Computational and statistical challenges

Track Classification: Computational and statistical methods

Contribution ID: **36** Type: **Oral**

The CARMENES radial velocity instrument: performance and results

Wednesday 20 March 2019 10:15 (15 minutes)

The CARMENES high-precision spectrometer started operations in January 1, 2016 at the 3.5-m telescope of the Calar Alto Observatory. Since then, the CARMENES consortium is carrying out a 750-night survey searching for exoplanets around M dwarf stars, preferably in their habitable zones, using the radial velocity technique. CARMENES has the unique capability of providing continuous high-resolution spectroscopy in the visible and the near-infrared wavelength range, from 0.52 to 1.71 micron. The first 3 years of observations have demonstrated the excellent performance of CARMENES and have provided us with insight into the exploitation potential of its visible and near-infrared channels. A number of exoplanets have been published so far and observations continue for tens of bona-fide planet candidates. CARMENES is also showing its potential as a workhorse in the study of exoplanet atmospheres. In this talk I will discuss the CARMENES performance, focusing in particular on the near-infrared channel, and highlight the main results obtained during the first 3 years of operations.

Author: Dr RIBAS, Ignasi (ICE/CSIC & IEEC)

Presenter: Dr RIBAS, Ignasi (ICE/CSIC & IEEC)

Session Classification: NIR instruments

Track Classification: Instruments in nIR

Contribution ID: **40** Type: **Oral**

Extremely Precise Radial Velocities: From Periodic Signals to Planet Detections

Monday 18 March 2019 11:00 (20 minutes)

It is quite common to find periodic signals in time series of precise radial velocities that cannot unambiguously be attributed either to a planetary companion or to intrinsic variability of the star. In such cases, plausibility criteria (e.g., fit quality, expected "typical"RV jitter, dynamical stability) and different types of additional information (e.g., stability of line profiles or line bisectors, color dependence of RVs, activity indicators, photometry) have been used to decide between the two possibilities; sometimes a clear conclusion is just not possible.
I will present methods intended to separate planet detections from RV "noise"with emphasis on K giants and M dwarfs, and discuss the results.
K giants are particularly difficult in this respect, as they display relatively large intrinsic RV variations, which are only partially understood, and depend strongly on the specific parameters (temperature, gravity, evolutionary state) of each individual star. A survey of the literature shows rather large differences in the ways that intrinsic RV variability has been taken into account, and consequently in the reliability of published planets orbiting giant stars. I will report on progress towards compiling a consolidated sample of these planets.
The CARMENES instrument has been optimized and built specifically for an RV survey of M dwarfs. It covers multiple activity indicators and a wide wavelength range; the data reduction pipeline produces several diagnostics on line indices, line shapes, and color dependence of the RV by default. I will discuss how these are taken into account in the scientific exploitation of the CARMENES survey, in order to characterize M dwarf activity, and to establish low-mass planetary companions with high confidence.
I will conclude with some general "lessons learned"from these projects, regarding best practices in publishing planet detections in RV data, and the design of spectrographs and survey strategies that facilitate planet detections in the presence of stellar RV variability.

Author: Prof. QUIRRENBACH, Andreas (Landessternwarte, ZAH, U Heidelberg)

Presenter: Prof. QUIRRENBACH, Andreas (Landessternwarte, ZAH, U Heidelberg)

Session Classification: Stellar signal 2

Track Classification: Stellar signals

Contribution ID: **41** Type: **Poster**

Characterizing the M dwarf planet population with CARMENES

CARMENES is a large RV-survey for low-mass planets of M-stars. In contrast to other M-star surveys its main focus are M3-M4V stars.

One of its aims is to determine the frequency of planets with periods of less than 50 days. Although the survey is still on-going, we have started to develop a method to determine the detection limits for each star. The basic idea is to simulate the RV-signal of all possible planets and then to calculate which of these would have been detected using the times and the accuracy of the RV-measurements obtained with CARMENES. In a first step we use only those stars for which 50 RV-measurements have already been obtained with CARMENES where no planets have been detected. We discuss the influence of eccentricity of the orbits, the multiplicity and the accuracy of the measurements on the detection limit.

In a second step, we will use those results for planet population synthesis. We will simulate the CARMENES survey observing a synthetic planet population produced by a global planet formation and evolution model. Using actual CARMENES measurements, we can determine which planets would not be detected and apply the resulting bias. The remaining subpopulation of detectable planets can be compared with the observed sample to constrain formation theories and make predictions about yet to be detected planets.

Author: SABOTTA, Silvia (Thüringer Landessternwarte / Thuringian State Observatory)

Presenter: SABOTTA, Silvia (Thüringer Landessternwarte / Thuringian State Observatory)

Track Classification: Others

Contribution ID: **42** Type: **Poster**

Optomechanical and thermal design of a wide bandwidth, high precision Rubidium locked Etalon calibrator

Reliable, high precision wavelength calibration is a bottleneck for commissioning a number of the next generation of Doppler spectrographs. We have developed a method to reference a wide bandwidth Etalon to a Rubidium transition to enable long-term stability and precision in the range below 10 cm/s. A key part of the whole instrument is the Etalon assembly itself. We strive to reach maximum passive stability, which requires careful consideration of the Etalon optical materials and coatings, the mechanical design of the holder and the enclosure, and the thermal control with layers of active thermal shells. In addition, the Rubidium spectroscopy unit, which ultimately provides the reference point for the whole spectrum, needs to be designed for optimal mechanical stability and isolation from environmental changes. Here we discuss details of the optomechanical design and lab tests of these subassemblies, on our way to final integration of an observatory-ready instrument.

Authors: Mr FEGER, Tobias (Macquarie University); Prof. SCHWAB, Christian (Macquarie University); Dr STUERMER, Julian (The University of Chicago); Prof. SEIFAHRT, Andreas (The University of Chicago); Dr GUREVICH, Yulia (Macquarie University); Mr ROGOZIN, Dmytro (KU Leuven); Dr FUEHRER , Thorsten (Technische Universität Darmstadt); Dr HALVERSON, Samuel (MIT Kavli Institute); Dr TERRIEN, Ryan (Carleton College); Dr LEGERO, Thomas (Physikalisch-Technische Bundesanstalt); Mr ANAGNOS, Theodoros (Macquarie University); Prof. COUTTS, David (Macquarie University); Dr RASKIN, Gert (KU Leuven); Prof. WALTHER, Thomas (Technische Universität Darmstadt); Prof. BEAN, Jacob (The University of Chicago); Prof. QUIRRENBACH, Andreas (Landessternwarte Heidelberg)

Presenter: Mr FEGER, Tobias (Macquarie University)

Track Classification: Instrument and calibration challenges

Contribution ID: **43** Type: **Poster**

Calibrating SPIRou in Wavelength

Abstract: In order to measure stellar radial velocities at high precision, an accurate wavelength solution is of paramount importance. To achieve such a solution, hollow-cathode (HC) lamps have frequently been used (e.g. on HARPS, SOPHIE). By identifying and cross-matching their spectral lines with very precise catalogues, a pixel-wavelength correlation can be generated. However, these spectral lines are irregularly spaced and of highly varying intensity, and the resulting wavelength solutions are accurate only to the meter-per-second level.

Therefore, to improve the wavelength calibration, different solutions have been sought. One is the use of a Fabry-Pérot (FP) etalon; this provides a multitude of lines which are evenly spaced but whose wavelength is not accurately known. Combined with a hollow-cathode lamp to supply an absolute wavelength identification of the FP lines, it serves to better constrain the wavelength solution. Such a HC-FP combination is used by e.g. CARMENES, ESPRESSO.

In this contribution, we will present the development of the SPIRou wavelength solution. SPIRou makes use of a UNe hollow-cathode lamp, with a plethora of catalogued rays in the near infrared, and a Fabry-Pérot etalon which generates lines covering the whole domain. We describe the different approaches tested, challenges encountered and lessons learned.

Authors: HOBSON, Melissa (Laboratoire d'Astrophysique de Marseille); Prof. BOISSE, Isabelle (Aix Marseille Univ, CNRS, CNES, LAM, Marseille, France); BOUCHY, François; Dr ARTIGAU, Etienne (Institut de Recherche sur les Exoplanètes (IREx), Département de Physique, Université de Montréal,); Dr COOK, Neil (Institut de Recherche sur les Exoplanètes (IREx), Département de Physique, Université de Montréal,); Dr MOUTOU, Claire (Canada-France-Hawaii Telescope Corporation, 65-1238 Mamalahoa Hwy, Kamuela, HI 96743, USA); SPIROU TEAM

Presenter: HOBSON, Melissa (Laboratoire d'Astrophysique de Marseille)

Track Classification: Instrument and calibration challenges

Contribution ID: **44** Type: **Oral**

FIOS: A Fabry Perot Instrument for O2 Searches

Tuesday 19 March 2019 17:30 (15 minutes)

With new missions and surveys such as TESS and SPECULOUS, the discovery of the first transiting, potentially earth-like planets is just around the corner. Once discovered, those planets will immediately become the focus of observations in search of atmospheric biomarkers such as H2O, CH4, O3, and O2. Recent studies suggest the latter will be best detected from the ground. Here we present a study of technical and observational parameters which will produce the most sensitive observations of O2 using instrumentation on the next generation of extremely large telescopes (ELTs). Our study suggests spectral resolution in excess of R˜100,000 is optimal for O2 detection. Therefore, we have developed a concept instrument based on an array of Fabry Perot Interferometers capable of achieving spectral resolutions in excess of R˜100,000 on ELTs. Despite its high spectral resolution, the concept instrument has modest dimensions, and allows high throughput. We discuss simulations results, suggesting that such an instrument can reduce the number of observed transits needed for molecular oxygen detection by 30% and more. Finally, we discuss design parameters and the unique aspects that need to be taken into account in the design of such an instrument, and present initial data from a lab pathfinder demonstrating its capabilities.

Author: Dr BEN-AMI, Sagi (Smithsonian Astrophysical Observatory)

Co-authors: Dr LOPEZ-MORALES, Mercedes (Smithsonian Astrophysical Observatory); Dr GONZALEZ ABAD, Gonzalo (Smithsonian Astrophysical Observatory); Mrs RUKDEE, Surangkhana (Harvard University); Dr SZENTGYORGYI, Andrew (Smithsonian Astrophysical Observatory)

Presenter: Dr BEN-AMI, Sagi (Smithsonian Astrophysical Observatory)

Session Classification: Optical challenges

Contribution ID: **45** Type: **Poster**

NEID fiber feed and barycentric correction

NEID is a high resolution (R˜100,000) fiber - fed Radial Velocity (RV) spectrograph, that will be commissioned at the 3.5 m WIYN telescope at Kitt Peak, USA. In this presentation, I will discuss the details of the NEID fiber feed, which contains octagonal and circular fibers. I shall discuss and share techniques we used to polish these fibers in custom fused silica pucks, FRD, scrambling and performance and testing of sub-sections of the feed.

To achieve the 1 cm/s precision in barycentric correction requires knowing the time of the observation to about 0.3 seconds, and an exposure meter. At this level of precision the flux variability depends on wavelength. I will discuss the design, integration and testing of NEID's chromatic exposure meter (R ˜ 100), which will potentially enable barycentric correction separately for each of NEID's 118 spectral orders. I shall also discuss the design, testing and installation of the exposure meter. Finally, I shall talk about Barycorrpy, the Python implementation of Barycorr (Wright and Eastman 2014) which is now in use in the pipelines of HPF, CARMENES, and NEID.

Authors: Mr KANODIA, Shubham (Pennsylvania State University); Prof. MAHADEVAN, Suvrath (Penn State University); Dr NEID TEAM

Presenter: Mr KANODIA, Shubham (Pennsylvania State University)

Track Classification: Error budget in EPRV

Contribution ID: **46** Type: **Poster**

Echelle++, a Fast Generic Spectrum Simulator

We present the software package Echelle++, an open-source C++ code to simulate realistic raw spectra based on the Zemax model of any spectrograph, with a particular emphasis on cross-dispersed Échelle spectrographs.
Echelle++ generates realistic spectra of astronomical and calibration sources, with accurate representation of optical aberrations, the shape of the point-spread function, detector characteristics, and photon noise. It produces high-fidelity spectra fast, a very important feature when testing data reduction pipelines with a large set of different input spectra, when making critical choices about order spacing in the design phase of the instrument, or while aligning the spectrograph during construction.
Echelle++ also works with low-resolution, low signal-to-noise, multi-object, IFU, or long-slit spectra, for simulating a wide array of spectrographs. We chose to initially generate our own spectrograph model from the optical prescription in Zemax. Echelle++ can then be used independently, without access to commercial ray tracing software.

Authors: STUERMER, Julian (University of Chicago); Prof. SEIFAHRT, Andreas (The University of Chicago); Mr ROBERTSON, Zachary (University of Chicago); Prof. BEAN, Jacob (The University of Chicago); Dr SCHWAB, Christian (Macquarie University)

Presenter: STUERMER, Julian (University of Chicago)

Track Classification: From raw spectra to EPRV: RV pipelines

Contribution ID: **47** Type: **Oral**

iLocater: Moving from design to fabrication

Wednesday 20 March 2019 11:30 (15 minutes)

iLocater is a next-generation precision radial velocity spectrograph under development for the Large Binocular Telescope (LBT). The instrument has three major subsystems which are currently undergoing simultaneous development: a single-mode fiber fed high-resolution (R˜150,000-240,000) NIR echelle spectrograph, an adaptive optics fed fiber-injection system, and a fabry-perot etalon based wavelength calibration unit. We present a design, performance and status update for iLocater and its individual subsystems as the instrument moves from design to fabrication.

Authors: Dr CRASS, Jonathan (University of Notre Dame); Prof. CREPP, Justin (University of Notre Dame)

Co-authors: Mr BECHTER, Andrew (University of Notre Dame); Dr KING, David (University of Cambridge); AIKENS, David (Savvy Optics Corp); MASON, Joaquin (Fathom Imaging Systems); SANDS, Brian (University of Notre Dame); HAMPER, Randall (University of Notre Dame); BECHTER, Eric (University of Notre Dame); KETTERER, Ryan (University of Notre Dame); SMOUS, James (University of Notre Dame); REYNOLDS, Robert (Large Binocular Telescope Observatory); HINZ, Philip (University of Arizona); MONTOYA, Manny (University of Arizona); KOPON, Derek (Harvard Smithsonian Center for Astrophysics); CAVALIERI, David (University of Notre Dame); Prof. SCHWAB, Christian (Macquarie University); Dr FEGER, Tobias (Macquarie University); MULLIN, Scott (University of Notre Dame); SKRUTSKIE, Michael (University of Virginia)

Presenter: Dr CRASS, Jonathan (University of Notre Dame)

Session Classification: NIR instruments

Track Classification: Instruments in nIR

Contribution ID: **49** Type: **Poster**

Error sources for the Automated Planet Finder

We have analyzed four years of Automated Planet Finder (APF) data to understand the error sources in the measured radial velocities. Our approach combines two data sets, long term measurements on a few standard stars and an intense campaign observing simultaneously observing two stars with both the APF and the PFS on Magellan. We find that, despite the strong similarities between the APF's *Levy* spectrometer and the PFS, the PFS performs markedly better with a 5 minute intrinsic uncertainty of ˜60 cm/s as opposed to the *Levy's* ˜150 cm/s. This error source is likely from the star moving on the aperture and we detail our planned improvements to upgrade the spectrometer. We also find hints of a seasonal zero point shift in the *Levy's* performance, related to temperature control system of the instrument.

Authors: HOLDEN, Bradford (University of California Observatories); BURT, Jennifer (MIT)

Presenter: HOLDEN, Bradford (University of California Observatories)

Track Classification: Error budget in EPRV

Contribution ID: **51** Type: **Oral**

Precision NIR RM effect observations with the Habitable-zone Planet Finder

Thursday 21 March 2019 10:00 (15 minutes)

Significant progress has been made in recent years in measuring the sky-projected obliquity distribution of early-type planet hosting systems via precise Rossiter-McLaughlin (RM) effect observations. However, currently only two M-dwarf systems, GJ 436 and Kepler-45, have published obliquities—and interestingly GJ 436 is observed to be misaligned. With such a sparse sample, key questions remain about the dynamical histories of M-dwarfs at the fully convective boundary. The advent of stabilized extremely precise RV spectrographs in the near-infrared (NIR) are opening the doors to answering these questions, capitalizing on the large RM-effect amplitudes produced by transiting exoplanets orbiting around rapidly-rotating M-dwarfs. In this talk, we will discuss recent precision RM effect observations of fully-convective M-dwarfs with the Habitable-zone Planet Finder (HPF), a stabilized NIR spectrograph recently commissioned on the 10m Hobby-Eberly Telescope (HET) at McDonald Observatory. We will discuss recent RM effect observations of the transit of TRAPPIST-1b, early results of which are consistent with a well-aligned orbit. We will discuss the merits and limitations of the HET/HPF queue to observe RM effects of M-dwarfs, utilizing the excellent stability of HPF, large collecting area of HET, and the short transit durations of M-dwarf planets. Finally, we will discuss future planned observations in the TESS era, with TESS being expected to discover a multitude of M-dwarf planet systems favorable for precise RM effect measurements in the NIR.

Author: Mr STEFANSSON, Gudmundur (Penn State University)

Co-author: THE HPF TEAM

Presenter: Mr STEFANSSON, Gudmundur (Penn State University)

Session Classification: Other

Track Classification: Others

Contribution ID: **52** Type: **Poster**

Identifying chromospheric activity-sensitive spectral lines in the CARMENES VIS and NIR spectral range of M dwarfs.

In this contribution we use visible and near-infrared CARMENES spectra of M dwarfs to search for chromospheric activity-sensitive spectral lines in addition to the well known NaI D1, D2 HeI D3, H_alpha and CaII IRT lines, HeI 10830 AA, P_gamma and P_beta lines. To identify lines with a significant chromospheric contribution we have used the spectral subtraction technique, that is by subtraction of a synthesized stellar spectrum constructed using artificially rotationally broadened and radial-velocity shifted spectrum of an inactive star chosen to match the spectral type and luminosity class of the active star under consideration. We confirm the new activity-sensitive lines analyzing the correlation with the other well known activity indicators in the same spectra and their temporal evolution. This selection of lines will be used to check the influence in spectral region used to derive RV and help to solve the problem of stellar activity in RV measurements to search for exoplanet around these stars.

Authors: MONTES, David (UCM); LÓPEZ-GALLIFA, Álvaro (UCM); LABARGA, Fernando (UCM)

Presenter: MONTES, David (UCM)

Track Classification: Stellar signals

Contribution ID: **53** Type: **Oral**

Studying Radial-velocity variations of active stars in the CARMENES Survey for Exoplanets

Monday 18 March 2019 09:30 (20 minutes)

Understanding the effect of stellar activity on the measured radial velocity (RV) is essential for the reliable detection of exoplanets around stars. It becomes even more vital when we are searching for low-mass planets around M-dwarfs, which are known to be particularly affected by active regions. Photospheric activity features in M-dwarfs stem from the depth of the convective layers and manifest themselves on the stellar disc as cool spots and hot faculae. The shape of the spectral line profiles gets distorted due to the temperature contrast between the photosphere and active regions depending on the sensitivity of the lines to temperature. Finding and treating activity-sensitive spectral lines in M-dwarfs is not trivial since atomic lines are heavily blended between themselves and with molecular bands. However, since the temperature contrast is wavelength dependent the distortion of line profiles tends to be more pronounced at shorter wavelengths and diminishes toward longer ones. Therefore, the amplitude of spot/faculae-induced RV variations is larger in the blue region of the spectrum compared to the red one (chromaticity). The CARMENES spectrograph covers a wide spectral range of 0.52 to 0.96 μm for the visible and 0.96 to 1.71 μm for the near-infrared and is ideal for studying the difference in the amplitude of the RV jitters.
In the CARMENES survey, we observed about 340 nearby M-dwarfs from January 2016 to November 2018. A sample of 53 highly active stars is selected that show significant RV excursion due to activity. However, only half of these targets show chromaticity in their radial velocities. We studied different parameters of the chromatic stars such as spectral type, vsini, inclination of the rotation axis, chromospheric activity indicators (e.g. the H-alpha and CaII IRT line strengths), and parameters characterizing the average absorption line shape (aka “dLW”and “CCF parameters”) and compare them to the remaining known active stars in the CARMENES sample which do not show chromatic behavior. We wish to understand why not all active stars show chromaticity and determine in which parameters those that show it and those that do not differ.

Author: Ms SADEGI, Sepideh (Landessternwarte/MPIA Heidelberg)

Co-authors: Dr REFFERT, Sabine (Landessternwarte Heidelberg); Dr KUERSTER, Martin (MPIA Heidelberg); QUIRRENBACH, Andreas (U Heidelberg); Ms KOSSAKOWSKI, Diana (MPIA Heidelberg); Dr TAL-OR, Lev (Tel Aviv University); ZECHMEISTER, Mathias (Georg-August Universität Göttingen); REINERS, Ansgar (Georg-August Universität Göttingen); Ms LAFARGA, Marina (Institut de Ciencies de l’Espai)

Presenter: Ms SADEGI, Sepideh (Landessternwarte/MPIA Heidelberg)

Session Classification: Stellar signals 1

Track Classification: Stellar signals

Contribution ID: **54** Type: **Oral**

Automated data reduction pipelines for the HPF and NEID spectrometers

Thursday 21 March 2019 11:30 (20 minutes)

The precision radial velocity community is pushing spectrometer hardware to new and ever more exciting stability levels that support a velocity precision of ˜1 m/s in the near-infrared, and sub 50 cm/s in the visible. These developments must be backed by increasingly sophisticated software algorithms and data reduction pipelines that can realize the potential of the new instruments. I will describe the pipelines that we have developed for the HPF (0.8 - 1.3 microns) and NEID (0.38 - 0.92 microns) PRV spectrometers. This will include algorithmic advances that allow us to more fully exploit our astronomical data, and automation techniques that simplify the user experience in going from on-sky observations to reliable radial velocities. Some of the algorithms we are utilizing include sophisticated up-the-ramp image processing for HPF's H2RG detector, polygon clipping image rectification and alias correction, and synthetic modeling of telluric absorption and emission. I will also touch on computational challenges that we have encountered in developing the NEID pipeline, particularly in light of the instrument's very large band-pass, and subsequent large data volume. The HPF pipeline has been regularly running since summer 2018, while the NEID pipeline will be ready for deployment coincident with instrument commissioning in 2019.

Authors: BENDER, Chad (University of Arizona); THE HPF AND NEID TEAMS

Presenter: BENDER, Chad (University of Arizona)

Session Classification: From raw spectra to EPRV: RV pipeline

Track Classification: From raw spectra to EPRV: RV pipelines

Contribution ID: **55** Type: **Poster**

New Astrophysical Insights into Radial Velocity Jitter

For nearly 20 years, the California Planet Search (CPS) has simultaneously monitored precise radial velocities and chromospheric activity levels of stars from Keck observatory to search for exoplanets. This sample provides a useful set of stars to assess the dependence of RV jitter on various astrophysical processes. We measure astrophysical jitter for ˜650 stars in the CPS covering a wide range of stellar parameters (effective temperature, surface gravity, and activity, among others). We highlight empirical evidence for two regimes of RV jitter: activity-dominated and convection-dominated. Combined, these regimes enable us to trace out the jitter evolution of stars – a useful complement to rotation-activity relations. As an outcome of this effort, we present the discovery of several new planets around subgiant stars, including potentially the first known 3-planet systems, increasing the number of known RV planets around subgiant stars by nearly 15%. We also identify additional candidate planetary systems requiring further follow-up as well as a number of non-planetary companions to subgiants. Finally, we calculate possible transit times, durations, depths, and probabilities for all known CPS planets around subgiant stars in time for TESS observations and follow-up.

Author: Mr LUHN, Jacob (Penn State University)

Co-authors: Prof. BASTIEN, Fabienne (Penn State University); Prof. WRIGHT, Jason (Penn State University); Prof. HOWARD, Andrew (Caltech); Prof. ISAACSON, Howard (UC Berkeley); Prof. JOHNSON, John (Harvard-Smithsonian Center for Astrophysics)

Presenter: Mr LUHN, Jacob (Penn State University)

Track Classification: Stellar signals

Contribution ID: **57** Type: **Oral**

MAROON-X: An Earth-Finder Spectrograph for the Gemini Observatory

Thursday 21 March 2019 09:45 (15 minutes)

Exoplanet surveys have recently progressed to the point of discovering small, potentially terrestrial planets orbiting in circumstellar habitable zones. Assessing the true degree of habitability of these worlds requires gaining knowledge of both their bulk and atmospheric properties. In this talk I will summarize the development of MAROON-X, which is a high precision radial velocity spectrograph that is scheduled to be commissioned at Gemini North as a visitor instrument in early 2019. MAROON-X is designed to measure the masses, and thus constrain the densities of potentially Earth-like worlds around late M dwarfs. I will describe how MAROON-X will be used in conjunction with facilities like TESS, JWST, and the ELTs to make the first credible searches for habitable environments beyond our Solar System.

Author: Dr STUERMER, Julian

Presenter: Dr STUERMER, Julian

Session Classification: Future EPRV instruments

Track Classification: Future instruments

Contribution ID: **58** Type: **Poster**

Statistical analysis of periodograms standardized by 3D hydrodynamical simulated time series of stellar surfaces

When the noise affecting time series is colored (i.e. frequency dependent) with unknown statistics, a difficulty for the detection of periodic signals is to control the true significance level of the test outcome.

Recent hydrodynamic simulations, performed in 3 dimensions, are able to generate reliable time series of convection, which is a stochastic colored noise for exoplanet detection. The objective of this work is to investigate whether these 3D simulated stellar noise training data sets could improve the detection.

Assuming the reliability of these synthetic time series, we propose to use them to standardize the periodogram of the data under test. We analyze the statistics and the performances of different detection tests applied to these new periodograms.

In the case of regular sampling, we show that the proposed standardization leads to powerful tests whose false alarm and detection rates can be accurately (analytically) controlled. New adaptive tests, from the literature in Statistics (e.g. Higher-Cristiscm and Berk Jones tests), never used in the exoplanet community, are shown to be particularly interesting to detect RV signatures that deviate from pure sinusoidal oscillations. In the case of irregular sampling, we demonstrate that combining the proposed periodograms standardization with bootstrap techniques also allow to derive consistent FA rate estimates. Consequently, if reliable time series of the colored noise are available, they can constitute a useful tool to derive detection tests that are both powerful and reliable.

Authors: Dr SULIS, Sophia (Austrian Academy of Science, Space Research Institute); Dr MARY, David (Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS); Dr BIGOT, Lionel (Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS)

Presenter: Dr SULIS, Sophia (Austrian Academy of Science, Space Research Institute)

Track Classification: Computational and statistical methods

Contribution ID: **59** Type: **Oral**

A fundamental test of planet formation: searching for low-mass planets around metal-poor stars

Thursday 21 March 2019 10:15 (15 minutes)

As the number of known super-Earths and Neptune-like planets keeps growing, the properties and frequency of such systems start to be revealed. Planet formation models suggest that these low-mass planets, unlike giant planets, should be frequent around stars with low metallicities. But this theoretical prediction still needs to be observationally confirmed.
I will present the analysis of a decade-long radial-velocity survey of metal-poor stars with the HARPS spectrograph. In this survey, we find a significantly lower frequency of low-mass planets, when compared with results for stars with solar metallicity. These results challenge the predictions of the standard core-accretion theory, strengthening the idea that planets with lower masses which form in metal-poor disks may not migrate far before the disk dissipates, ending up at larger orbital periods and thus being still undetectable.

Author: FARIA, João (Institute of Astrophysics and Space Sciences)

Co-authors: Dr SANTOS, Nuno (IA/U. Porto); Dr FIGUEIRA, Pedro (ESO and IA/U. Porto)

Presenter: FARIA, João (Institute of Astrophysics and Space Sciences)

Session Classification: Other

Track Classification: Others

Contribution ID: **60** Type: **Poster**

Near Infrared Optical Frequency Comb Calibrators for the Habitable-Zone Planet Finder

We describe the laser frequency comb that is now installed and operating as the primary wavelength calibrator for the Habitable Zone Planet Finder (HPF) spectrograph at the 10 m Hobby-Eberly Telescope. The laser frequency comb, with 30 GHz mode spacing, is built around a combination of electro-optic and integrated-photonic technologies to address the challenges of bandwidth, mode spacing, and robustness. The central tooth of the comb is the 1064 nm continuous wave (CW) light from a semiconductor laser that feeds waveguide electro-optic modulators driven by a 30 GHz microwave source. This results in a comb of approximately 100 teeth spaced exactly by the microwave drive frequency. The CW laser, microwave source, and all other frequencies in the system are referenced to a GPS-disciplined clock that provides absolute traceability to the SI second with fractional uncertainty below 1e-12 at 1 night of averaging. The initial comb is amplified, spectrally broadened and temporally compressed to a pulse width of 70 fs, and then focused into a 25 mm long nonlinear silicon nitride waveguide. The waveguide provides the combination of tight confinement and engineered dispersion for nonlinear spectral expansion of the 30 GHz comb across 700-1600 nm with only 525 mW of incident average power (18 pJ of pulse energy). This low power reduces the thermal loading and aides long-term operability. Static and programmable amplitude filters are used to flatten the spectral envelope across the HPF band of 800-1300 nm. The laser frequency comb has been running autonomously and continuously since May 2018, and we have used it to achieve on-sky stellar RV's with precision near 1.53 m/s. We have further shown that the intrinsic stability of the HPF and comb support RV precision below 10 cm/s. This same electro-optic frequency comb architecture can be employed for coverage from <600 nm to >2500 nm.

In addition to the 30 GHz LFC, we have built and installed an evacuated and temperature-controlled plane-parallel Fabry-Perot etalon as a supplementary calibrator for the HPF. Extensive pre-deployment testing allowed us to simultaneously track multiple Fabry-Perot resonances between 800 and 1300 nm. While showing slow linear drift and excellent frequency stability of the etalon modes below 1e-9 per day, these laboratory tests revealed chromatic variation in the linear drift not supported by a simple description of the etalon. This study has continued post-deployment, where interleaved comb and etalon exposures at the HPF provide the ability to cross-calibrate and track the drift of each individual mode of the etalon relative to the absolute reference provided by the comb. Such measurements across the full HPF bandpass with precision <1m/s have further confirmed unexpected chromatic structure in the etalon drift. Updated results and our interpretation of the etalon's chromatic drift properties will be presented.

Authors: DIDDAMS, Scott (NIST and Univ. of Colorado); (FOR LASER FREQUENCY COMB AND HPF TEAMS)

Presenter: DIDDAMS, Scott (NIST and Univ. of Colorado)

Track Classification: Instrument and calibration challenges

Contribution ID: **61** Type: **Poster**

Laser Frequency Combs for spectrograph calibration from blue to near infrared

Astronomical laser frequency combs (LFCs) have become invaluable tools for precision astronomical spectroscopy. By serving as extremely stable wavelength references, they are ideal for searching Earth-like extrasolar planets using the radial-velocity method. LFCs generate a regular pattern of sharp emission lines, whose optical frequencies are referenced to an atomic clock. The relative stability of two individual LFCs on the cm/s level was demonstrated during a measurement campaign at the HARPS spectrograph in the visible spectral range (450nm-700nm). To make the LFC suitable as calibrators for the new generation NIR spectrographs we recently were able to extend the spectral coverage of the comb structure to 2.3µm on the infrared side of the spectrum.

Authors: Dr STEINMETZ, Tilo (Menlo Systems GmbH); Dr PROBST, Rafael (Menlo Systems GmbH); Dr WU, Yuanjie (Menlo Systems GmbH); Dr HOLZWARTH, Ronald (Menlo Systems GmbH)

Presenter: Dr STEINMETZ, Tilo (Menlo Systems GmbH)

Track Classification: Instrument and calibration challenges

Contribution ID: **62** Type: **Oral**

Effects of Tellurics in PRVs and Effectiveness of Mitigation Strategies

Monday 18 March 2019 17:20 (20 minutes)

We performed simulations using the Kurucz solar spectrum and TAPAS generated telluric spectra across a year with varying atmospheric conditions to quantify the effects of telluric contamination in PRVs. We chose the wavelength range from 350nm to 2.5 micron and assumed a spectral resolution of R=120,000 with no photon noise. We assumed perfectly known spectral PSF, wavelength solution, and stellar mask/template to isolate the effects of tellurics. We will illustrate the added RV error due to tellurics as a function of wavelength and telluric content. We compared two mitigation methods: dividing out the telluric spectrum then CCF, vs. forward modeling. For the forward modeling approach, we assessed the impact of imperfect knowledge of the atmospheric line profile by fitting the simulated observed spectra using an input telluric spectrum with wrong line profiles. We conclude that forward modeling is a more effective method in mitigating tellurics. This study is part of a NASA mission concept study, EarthFinder.

Authors: Dr WANG, Sharon Xuesong (Carnegie DTM); Dr PLAVCHAN, Peter (George Mason University); Ms LATOUF, Natasha (George Mason University)

Presenter: Ms LATOUF, Natasha (George Mason University)

Session Classification: Telluric contamination in EPRV

Track Classification: Telluric contamination

Contribution ID: **63** Type: **Poster**

Simulations for Planning Upcoming Exoplanet Surveys

Future direct imaging missions such as WFIRST, HabEx, and LUVOIR aim to catalog and characterize Earth-analogs around nearby stars. The observing strategy and science yield are strongly dependent on the frequency of Earth-like planets, and precursor knowledge of which stars specifically host suitable planetary systems. Ground- or space-based radial velocity surveys can potentially identify targets and optimal observations times at a fraction of the cost of blind direct imaging surveys. We present the first phases of simulations of such surveys. We consider multiple telescopes, including their locations, weather conditions, observation time limitations, and instrument sensitivities. Multiple target selection algorithms and cadences are considered. We calculate realistic radial velocity uncertainties based upon the known stellar properties of nearby direct imaging targets including effective temperature, metallicity, and surface gravity. We next inject and recover the masses and orbital parameters of simulated planets using current demographics, estimating the effectiveness of the different configurations.

Authors: NEWMAN, Patrick (George Mason University); Prof. PLAVCHAN, Peter (George Mason University); Prof. CREPP, Justin (University of Notre Dame); DULZ, Shannon (Notre Dame); STARK, Chris (Space Telescope Science Institute); Dr KANE, Stephen (University of California Riverside); MULDERS, Gijs (University of Chicago); MORGAN, Rhonda (NASA JPL); GAUDI, Scott (Ohio State University); SEAGER, Sara (MIT)

Presenter: NEWMAN, Patrick (George Mason University)

Track Classification: Observational strategies

Contribution ID: **64** Type: **Poster**

Combining visible and near-infrared high resolution spectroscopy with HARPS and NIRPS

The Near Infra-Red Planet Searcher (NIRPS) will join HARPS on the 3.6 m ESO telescope in La Silla, Chile in the summer of 2019. The new NIR arm will operate in the Y, J and H bands (973.79 to 1808.53 nm) with an AO-assisted guiding camera. Built with the specific goal of characterising exoplanets around M-dwarfs and achieving 1 m/s accuracy in the NIR, NIRPS will play an important role identifying possibly habitable worlds. Especially in the era of TESS, where we expect to find numerous planets orbiting cool dwarfs, having access to the NIR through instruments like NIRPS will be key in exoplanet research.

For early type M-dwarfs we expect a gain of 5 orders of magnitude in photon noise from HARPS to NIRPS. We will present the expected gain for a wide range of spectral types and demonstrate how the combination of NIRPS and HARPS will further presise mass measurements. Not only will we get a significant increase in signal-to-noise in the NIR for cool stars, but the NIR arm will also enable monitoring of stellar activity for all stellar types, and thus disentangling stellar activity from doppler motion caused by a planet.

Author: NIELSEN, Louise (University of Geneva)

Co-authors: BOUCHY, François; DUMUSQUE, Xavier (Université de Genève); CANTO, Bruno; Dr ARTIGAU, Etienne (Institut de Recherche sur les Exoplanètes (IREx), Département de Physique, Université de Montréal,); PEPE, Francesco (University of Geneva)

Presenter: BOUCHY, François

Track Classification: Instruments in nIR

Contribution ID: **65** Type: **Poster**

EarthFinder: A Probe-Class Mission Precise for a Radial Velocity Survey of our Nearest Stellar Neighbors to detect and characterize Earth-Mass Habitable Zone Analogs Using High-Resolution UV-Vis-NIR Echelle Spectroscopy

We present the science case for a 1.45 meter space telescope to survey the closest, brightest FGKM main sequence stars to search for Habitable Zone (HZ) Earth analogs using the precise radial velocity (PRV) technique at a precision of 1-10 cm/s. Our baseline instrument concept uses three diffraction-limited spectrographs operating in the 0.3-0.4, 0.4-0.9, and 0.9-2.4 microns spectral regions each with a spectral resolution of R=150,000˜200,000. Because the instrument utilizes a diffraction-limited input beam, each spectrograph arm will be extremely compact, less than 50 cm on a side, and illumination can be stabilized with the coupling of starlight into single mode fibers. With two octaves of wavelength coverage and a cadence unimpeded by any diurnal, atmospheric and most seasonal effects, EarthFinder will offer a unique platform for recovering stellar activity signals from starspots, plages, granulation, etc. to detect exoplanets at velocity semi-amplitudes currently not obtainable from the ground. Variable telluric absorption and emission lines may potentially preclude achieving PRV measurements at or below 10 cm/s in the visible and <50 cm/s in the near-infrared from the ground. Placed in an Earth-trailing (e.g. Spitzer, Kepler) or Lagrange orbit, the space-based cadence of observations of a star can be year-round at the ecliptic poles, with two 90-day “seasons” every 6 months in the ecliptic plane. This cadence and wavelength coverage will provide a distinct advantage compared to an annual ˜3-6 month observing season from the ground for mitigating stellar activity and detecting the orbital periods of HZ Earth-mass analogs (e.g. ˜6-months to ˜2 years). Finally, we have compiled a list of ancillary science cases for the observatory, ranging from asteroseismology to the direct measurement of the expansion of the Universe.

Authors: PLAVCHAN, Peter (George Mason University); TEAM, EarthFinder

Presenter: PLAVCHAN, Peter (George Mason University)

Track Classification: Future instruments

Contribution ID: **66** Type: **Oral**

Telluric emission and absorption correction in the HPF and NEID pipeline

Monday 18 March 2019 17:40 (20 minutes)

Emission and absorption from the Earth's atmosphere at infrared and optical wavelengths introduces a significant source of contamination for ground based precision RV spectroscopy. These telluric features not only add statistical noise and remove flux from our spectra, but introduce additional uncertainty because some of the telluric line strengths themselves are highly variable and not known a priori. I will present our latest methods for fitting and removing telluric emission and absorption in the HPF and NEID pipelines, and the potential of using these data for ancillary atmospheric science. We observe telluric emission simultaneously with the science data through a sky fiber that is offset from the science target. Telluric absorption is observed in the spectrum of the science target itself. We use laser frequency comb emission lines to measure our instrumental PSF at closely spaced regular intervals. To calculate the telluric emission line strengths, we simulate the level populations of the rovibrationally excited molecules (e.g. OH and O2) that give rise to the emission lines. To calculate the telluric absorption line strengths, we use atmospheric radiative transfer models to calculate the column densities of the absorbing species. Using the measured instrumental PSF and simulated line strengths, we then forward model the telluric emission and absorption lines and iteratively fit the forward model to the science data varying the molecular level populations until the best fit is found. These model fits not only provide a noise free way to correct for telluric emission and absorption, but also provide a long baseline of continuous observations for ancillary atmospheric science.

Author: KAPLAN, Kyle (The University of Arizona)

Co-author: THE HPF AND NEID TEAMS

Presenter: KAPLAN, Kyle (The University of Arizona)

Session Classification: Telluric contamination in EPRV

Track Classification: Telluric contamination

Contribution ID: **68** Type: **Poster**

NEID and HPF: Optical designs of two large, extreme precision Doppler spectrographs

NEID and HPF both were conceived to deliver ground-breaking precision in their wavelength regime. HPF has now been commissioned at the Hobby Eberly Telescope, while NEID is fully integrated and set to be deployed at WIYN in Summer 2019. The instruments both use 2x1 mosaic of the same RGL master grating at R4, with nearly 200mm beam diameter, in a white pupil configuration. The cross dispersion and camera systems are rather different, using distinctive methods to flatten the field and to deliver a design image quality that approaches the diffraction limit across most of the spectral range. We present the instrument optics and discuss some lessons learned in building these instruments. We also present the optical design of NEID telescope port with a high performance ADC and very tight optical specifications on fiber coupling.

Authors: Dr SCHWAB, Christian (Macquarie University); AND THE NEID AND HPF TEAMS

Presenter: Dr SCHWAB, Christian (Macquarie University)

Track Classification: Instrument and calibration challenges

Contribution ID: **69** Type: **Oral**

Better Radial Velocity Measurement Precision Through Organic Chemistry: The GMT Consortium Large Earth Finder (G-CLEF)

Thursday 21 March 2019 09:30 (15 minutes)

The GMT-Consortium Large Earth Finder (G-CLEF), is currently scheduled to be the first PRV-capable instrument on an ELT. G-CLEF embraces many design paradigms of earlier PRV instruments, especially the HARPSs. However, the G-CLEF design team is exploiting several novel technologies to deliver an exceptionally stable and calibratable spectrograph. In this talk, we provide an overview of the G-CLEF instrument, the challenges associated with designing a PRV instrument for ELT-scale apertures and then focus on those innovative design features of G-CLEF that should make it an exceptionally precise stellar velocimeter.

Authors: Dr SZENTGYORGYI, Andrew (Smithsonian Astrophysical Observatory); THE G-CLEF COLLABORATION

Presenter: Dr SZENTGYORGYI, Andrew (Smithsonian Astrophysical Observatory)

Session Classification: Future EPRV instruments

Track Classification: Future instruments

Contribution ID: **70** Type: **Oral**

Precise Near Infrared Radial Velocities With iSHELL

Wednesday 20 March 2019 11:45 (15 minutes)

We present our radial-velocities (RVs) with the iSHELL spectrograph at the NASA Infrared Telescope facility. Replacing the 25 year old CSHELL instrument, iSHELL offers improvements in spectral grasp (˜40x), resolution (70,000 versus 46,000), throughput, optics, and detector characteristics. Our primary goal with iSHELL is to characterize the precise radial-velocity performance of the methane isotopologue absorption gas cell in the calibration unit. Over the last two years, we've obtained 3-12 epochs of bright nearby RV standards as well as RV variables of our own. A new flexible telluric model allows for dynamic abundance ratios in Earth's atmosphere, and physically-motivated analytic fringing models account for internal reflections from the optics in the instrument. We've demonstrated 6 m/s precision on Barnard's star over one year, sufficient to confirm Neptune-mass planets around M Dwarfs discovered by the NASA TESS mission. With further development on the the non-standard blaze and line spread functions present in iSHELL data, we aim to achieve 3-5 m/s long-term precision, sufficient to detect terrestrial mass planets in the habitable zone of nearby M Dwarfs.

Authors: Prof. PLAVCHAN, Peter (George Mason University); BRYSON, Cale (George Mason University)

Presenter: Prof. PLAVCHAN, Peter (George Mason University)

Session Classification: NIR instruments

Track Classification: Instruments in nIR

Contribution ID: **71** Type: **Oral**

Rubidium traced Etalon wavelength calibrators: towards deployment at observatories

Tuesday 19 March 2019 10:15 (15 minutes)

Precise wavelength calibration is a persistent problem for highest precision Doppler spectroscopy. The ideal calibrator provides an extremely stable spectrum of equidistant, narrow lines over a wide bandwidth, is reliable over timescales of years, and simple to operate. Unlike traditional hollow cathode lamps, etalons provide an engineered spectrum with adjustable line distance and width, and can cover a very broad spectral bandwidth. We have shown that laser locked etalons provide the necessary stability with an ideal spectral format for calibrating precision Echelle spectrographs, in a cost-effective and robust package. Anchoring the Etalon spectrum to a very precisely known hyperfine transition of Rubidium delivers cm/s-level stability over timescales of years. We have engineered a fieldable system which is currently being constructed as calibrator for the Maroon-X, Hermes, KPF, FIES and iLocater spectrographs.

Authors: Prof. SCHWAB, Christian (Macquarie University); COUTTS, David; FEGER, Tobias; RASKIN, Gert; STUERMER, Julian; SEIFAHRT, Andreas; ROGOZIN, Dmytro; GUREVICH, Julia; QUIRRENBACH, Andreas (U Heidelberg); Dr HALVERSON, Sam (MIT); WALTHER, Thomas; FUEHRER, Thorsten; LEGERO, Thomas; Prof. TERRIEN, Ryan (Carleton College)

Presenter: Prof. SCHWAB, Christian (Macquarie University)

Session Classification: Instrument and calibration challenges

Track Classification: Instrument and calibration challenges

Contribution ID: **73** Type: **Oral**

Is telluric correction required for precise radial velocities?

Monday 18 March 2019 17:00 (20 minutes)

Stellar spectra are polluted with the absorption lines produced by the Earth's atmosphere. Earlier modeling work showed that a perfect telluric correction increases the radial velocity precision compared to masking the regions affected by telluric absorption. But what is the case for real observations? With CARMENES near-infrared spectra, I will show the impact of the telluric correction on the radial velocity precision effectively derived, before and after telluric correction using the synthetic transmission method Molecfit. I will discuss the advantages and limitations of the synthetic transmission methods. Finally, with ESPRESSO data, I will show the impact of the correction methods on the micro-telluric lines (< 2%) and their possible improvements.

Authors: Dr ULMER-MOLL, Solene (IA/U. Porto); Dr SANTOS, Nuno (IA/U. Porto); Dr FIGUEIRA, Pedro (ESO and IA/U. Porto); NEAL , Jason (Centro de Astrofisica da Universidade do Porto)

Presenter: Dr ULMER-MOLL, Solene (IA/U. Porto)

Session Classification: Telluric contamination in EPRV

Track Classification: Telluric contamination

Contribution ID: **74** Type: **Oral**

Line by line radial velocities to mitigate stellar activity

Monday 18 March 2019 10:10 (20 minutes)

Author: DUMUSQUE, Xavier (Université de Genève)

Presenter: DUMUSQUE, Xavier (Université de Genève)

Session Classification: Stellar signals 1

Track Classification: Stellar signals

Contribution ID: **75** Type: **Oral**

Electro-optic laser frequency comb for spectrograph calibration

Tuesday 19 March 2019 10:00 (15 minutes)

Laser frequency combs (LFCs) comprising thousands of evenly spaced laser lines with absolutely and precisely known optical frequencies can meet the calibration requirements for extreme precision in radial velocity measurements.

We present a LFC for accurate and precise spectrograph calibration in the near-infrared. The LFC is based on electro-optic modulation of a continuous-wave laser and provides comb lines readily resolvable by an astronomical spectrograph without the need for spectral filtering. After temporal compression and spectral broadening, the system currently provides more than 5'000 comb lines spaced by 14.5 GHz covering the wavelength range from 1280 nm to 1880 nm. The spectral coverage and the LFC's line spacing can be modified to accommodate the specific needs of the spectrograph. Owing to its all-fibre design, the system is alignment-free and of low operational complexity. As all critical components rely on mature optical telecommunication technology, the system is inherently robust and suitable for long-term and low-maintenance operation. Successful performance test of the LFC was performed on the GIANO-B spectrograph demonstrating a photon-noise-limited spectrograph calibration precision of <10 cm/s and an on-sky performance only limited by telluric interference. Current efforts are concentrated on extending the spectral span, which will lead to increased radial velocity calibration precision.

Authors: Mrs OBRZUD, Ewelina (Department of Astronomy, University of Geneva); LECOMTE, S. (CSEM); Dr WILDI, François (Department of Astronomy, University of Geneva); Dr PEPE, Francesco (Department of Astronomy, University of Geneva); HERR, Tobias (CSEM); BRASCH, V. (CSEM); BOUCHY, François (Department of Astronomy, University of Geneva); RAINER, M. (INAF Brera); HARUTYUNYAN, A. (INAF Fundación Galileo Galilei); CHAZELAS, Bruno (Department of Astronomy, University of Geneva); CECCONI, M. (INAF, Fincacion Galileo Galilei); GHEDINA, Adriano (INAF, Fundación Galileo Galilei); MOLINARI, Emilio (INAF, Fundación Galileo Galilei); KUNDERMANN, S. (CSEM)

Presenter: Mrs OBRZUD, Ewelina (Department of Astronomy, University of Geneva)

Session Classification: Instrument and calibration challenges

Track Classification: Instrument and calibration challenges

Contribution ID: **77** Type: **Oral**

Mitigating stellar signals to reveal other Earths: review on the impact of stellar activity on exoplanet detectability

Monday 18 March 2019 09:00 (30 minutes)

The first part of this review will be devoted to the different stellar processes leading to spurious radial velocities. They are due to magnetic activity (spots, plages, and flares to a lesser extent) and to flows at various scales (from granulation to meridional circulation), or a combination of both (inhibition of the convective blueshift in plages). The second part of the talk will review approaches which have been followed by various groups over the past years to characterize these effects and then to mitigate them to be able to reach small mass planet.

Author: Dr MEUNIER, Nadège (University of Grenoble)

Presenter: Dr MEUNIER, Nadège (University of Grenoble)

Session Classification: Stellar signals 1

Track Classification: Stellar signals

Contribution ID: **78** Type: **Oral**

Discussion: Stellar activity

Monday 18 March 2019 12:00 (30 minutes)

Session Classification: Stellar signal 2

Track Classification: Stellar signals

Contribution ID: **79** Type: **Oral**

Review: Telluric contamination

Monday 18 March 2019 16:30 (30 minutes)

Author: Prof. BLAKE, Cullen (University of Pennsylvania)

Presenter: Prof. BLAKE, Cullen (University of Pennsylvania)

Session Classification: Telluric contamination in EPRV

Track Classification: Telluric contamination

Contribution ID: **80** Type: **Oral**

Review: Error budge in EPRV

Tuesday 19 March 2019 09:00 (30 minutes)

Author: Dr HALVERSON, Sam (MIT)

Presenter: Dr HALVERSON, Sam (MIT)

Session Classification: Instrument and calibration challenges

Track Classification: Instrument and calibration challenges

Contribution ID: **81** Type: **Oral**

High Performance Infrared Detectors for EPRV Measurements

Tuesday 19 March 2019 09:30 (30 minutes)

Author: Dr BELETIC, Jim (Teledyne Imaging Sensors)

Presenter: Dr BELETIC, Jim (Teledyne Imaging Sensors)

Session Classification: Instrument and calibration challenges

Track Classification: Instrument and calibration challenges

Contribution ID: **82** Type: **Oral**

Review: Statistical Methods for Estimating Radial Velocities in the Presence of Stellar Activity

Tuesday 19 March 2019 11:00 (30 minutes)

Estimating precise radial velocities due to orbiting exoplanets in the presence of stellar activity is a challenging statistical problem. As instrumentation continues to improve, allowing for the detection of sub meter-per-second shifts, the effect of stellar activity becomes more problematic because the stellar activity can cause distortions in the spectra that mimic the RV of an orbiting exoplanet potentially leading to false detections. In this review, I will discuss various statistical methods that have been developed to address this issue, and suggest some additional routes forward.

Author: Dr FARIA, João (Institute of Astrophysics and Space Sciences, University of Porto)

Presenter: Dr FARIA, João (Institute of Astrophysics and Space Sciences, University of Porto)

Session Classification: Computational and statistical challenges

Track Classification: Computational and statistical methods

Contribution ID: **83** Type: **Oral**

Review: Light injection into EPRV spectrographs

Tuesday 19 March 2019 17:00 (30 minutes)

Author: Dr CHAZELAS, Bruno (University of Geneva)

Presenter: Dr CHAZELAS, Bruno (University of Geneva)

Session Classification: Optical challenges

Track Classification: Instrument and calibration challenges

Contribution ID: **84** Type: **Oral**

Review: Spectrograph design for EPRV

Tuesday 19 March 2019 16:30 (30 minutes)

Author: Prof. SUVRATH, Mahadevan (Penn State Unibversity)

Co-author: PEPE, Francesco (University of Geneva)

Presenter: Prof. SUVRATH, Mahadevan (Penn State Unibversity)

Session Classification: Optical challenges

Track Classification: Instrument and calibration challenges

Contribution ID: **85** Type: **Oral**

ESPRESSO

Wednesday 20 March 2019 08:15 (15 minutes)

Author: Prof. PEPE, Francesco

Presenter: Prof. PEPE, Francesco

Session Classification: VIS instruments

Track Classification: Instruments in VIS

Contribution ID: **86** Type: **Oral**

EXPRES

Wednesday 20 March 2019 08:30 (15 minutes)

Author: Ms ZHAO, Lily

Presenter: Ms ZHAO, Lily

Session Classification: VIS instruments

Track Classification: Instruments in VIS

Contribution ID: **87** Type: **Oral**

NEID

Wednesday 20 March 2019 09:30 (15 minutes)

Author: Dr ROBERTSON, Paul

Presenter: Dr ROBERTSON, Paul

Session Classification: VIS instruments

Track Classification: Instruments in VIS

Contribution ID: **88** Type: **Oral**

HARPS 3

Thursday 21 March 2019 09:15 (15 minutes)

Presenter: Dr THOMPSON, Sam

Session Classification: Future EPRV instruments

Track Classification: Future instruments

Contribution ID: **93** Type: **Oral**

HPF

Wednesday 20 March 2019 10:45 (15 minutes)

Author: Dr NINAN, Joe

Presenter: Dr NINAN, Joe

Session Classification: NIR instruments

Track Classification: Instruments in nIR

Contribution ID: **94** Type: **Oral**

Radial velocities with GIANO-B, the NIR spectrograph at TNG

Wednesday 20 March 2019 11:15 (15 minutes)

The NIR high resolution spectrograph GIANO, working in the wavelength range from 0.97 to 2.45 microns at a resolution of 50,000, was installed and commissioned at the Nasmyth-A focal station of the TNG in 2014. Through the GIARPS project, aimed to the simultaneous use of GIANO and HARPS-N spectrographs, GIANO was moved to the Nasmyth-B (re-naming the instrument GIANO-B) and modified in its configuration. This also provided a significant improvement in the instrument performances. GIANO-B, together with HAPRS-N, is carrying out a radial velocity survey searching for and characterising Hot Jupiters around young stars. We present the GIANO-B RV performances and the results obtained during the first year of observations.

Author: Dr CARLEO, Ilaria

Presenter: Dr CARLEO, Ilaria

Session Classification: NIR instruments

Track Classification: Instruments in nIR

Contribution ID: **96** Type: **Oral**

NIRPS on track to join HARPS on the ESO 3.6-m

Thursday 21 March 2019 09:00 (15 minutes)

The Near-InfraRed Planet Searcher (NIRPS) is a new ultra-stable near-infrared (YJH) spectrograph that will be installed on ESO 3.6-m Telescope in La Silla, Chile in begining 2020. Covering YJH bands with a spectral resolution of 100'000, NIRPS is part of a new generation of adaptive optics fiber-fed spectrographs. NIRPS will use a 0.4-arcsecond multi-mode fiber, half that required for a seeing-limited instrument, allowing a spectrograph design that is half as big as that of HARPS, while meeting the requirements for high throughput and high spectral resolution. A 0.9-arcsecond fiber will be used for fainter targets and degraded seeing conditions. NIRPS is designed to achieve a precision of 1 m.s-1 and will be operated simultaneously with HARPS. Here we describe the NIRPS main technical characteristics and the first tests of the Cassegrain Adapter made in lab with the AO system.

Authors: François Bouchy, René Dyon, François Wildi, Etienne Artigau, Nicolas Blind, Isabelle Boisse, Bruno Canto Martins, Bruno Chazelas, Ryan Cloutier, Xavier Delfosse, Xavier Dumusque, Pedro Figueira, Jonay Gonzales Hernandez, Christophe Lovis, Claudio Melo, Francesco Pepe, Rafael Rebolo, José Renan De Meideiros, Nuno Santos, Stéphane Udry, Gregg Wade, and the NIRPS team

Author: Prof. FRANÇOIS, Bouchy

Presenter: Prof. FRANÇOIS, Bouchy

Session Classification: Future EPRV instruments

Track Classification: Future instruments

Contribution ID: **97** Type: **Oral**

Review: RV pipelines

Thursday 21 March 2019 11:00 (30 minutes)

Author: Dr ROY, Arpita

Presenter: Dr ROY, Arpita

Session Classification: From raw spectra to EPRV: RV pipeline

Track Classification: From raw spectra to EPRV: RV pipelines

Contribution ID: **99** Type: **Oral**

SPIRou spectropolarimeter in operation at CFHT

Wednesday 20 March 2019 11:00 (15 minutes)

The near-infrared spectropolarimeter SPIRou is now in operation on the 3.6-m Canada-France-Hawaii telescope and recently started its survey. Thanks to its unique combination of a wide simultaneous spectral domain (0.98-2.35 μm, YJHK bands), a high throughput (>10% in H and K bands), a resolving power of 70'000, a radial-velocity precision close to 2 m/s, and polarimetric capabilities, SPIRou is expected to play a key role on the detection and characterization of planetary systems around nearby M dwarfs. Here we present the main characteristic of the instrument and the main results obtained during commissioning.

Authors: Jean-François Donati, Claire Moutou, François Bouchy, Etienne Artigau, Isabelle Boisse, Andres Carmona, Neil Cook, Xavier Delfosse, René Doyon, Pascal Fouqué, Melissa Hobson, and the SPIRou team

Authors: Jean-François Donati, Claire Moutou, François Bouchy, Etienne Artigau, Isabelle Boisse, Andres Carmona, Neil Cook, Xavier Delfosse, René Doyon, Pascal Fouqué, Melissa Hobson, and the SPIRou team

Author: BOUCHY, François

Presenter: BOUCHY, François

Session Classification: NIR instruments

Track Classification: Instruments in nIR

Contribution ID: **100** Type: **Poster**

Barycentric correction of long period exposure

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Authors: Mrs GORNEA, Andreea Ioana (DTU Space, National Space Institute, Denmark); Mr RASMUSSEN, Rene Tronsgaard (DTU Space, National Space Institute, Denmark)

Presenter: Mrs GORNEA, Andreea Ioana (DTU Space, National Space Institute, Denmark)

Track Classification: Error budget in EPRV

Contribution ID: **101** Type: **Poster**

Precision, consistency, and accuracy of astrocombs

...

Authors: Mr MILAKOVIC, Dinko (ESO); Dr PASQUINI, Luca (ESO)

Presenter: Mr MILAKOVIC, Dinko (ESO)

Track Classification: Instrument and calibration challenges

Contribution ID: **102** Type: **Poster**

AO-assisted spectrograph using few-mode fibers: coupling performance and modal noise

Author: Dr NICOLAS, Blind (Astronomy Department of the University of Geneva)

Presenter: Dr NICOLAS, Blind (Astronomy Department of the University of Geneva)

Session Classification: Instrument and calibration challenges

Track Classification: Instrument and calibration challenges

Contribution ID: **103** Type: **Poster**

Selected stars for the blind radial velocity ESPRESSO survey

We screened the most suitable G, K and M nearby stars for the detection of Earth-class exoplanets with ESPRESSO. For most of these stars, we investigate the existence of stellar binaries. We derived the activity level using chromospheric activity indexes log(R'HK) and Ha, as well as the projected rotational velocity v sin i. For cases where planet companions are already known we also accessed the possibility that additional planets may exist in the habitable zone using dynamical arguments. We selected the best 45 stars that match our criteria for detectability of an Earth twin. Some of the stars presented and discussed in this poster will constitute the ESPRESSO GTO catalog the RV blind search for earth-class planets. They can also be used for any other work requiring a detailed spectroscopic characterization of stars in the solar neighborhood.

Author: Mr HOJJATPANAH, Saeed (Institute of Astrophysics and Space Sciences University of Porto)

Presenter: Mr HOJJATPANAH, Saeed (Institute of Astrophysics and Space Sciences University of Porto)

Contribution ID: **104** Type: **Oral**

NASA Exoplanet Exploration Program and precision radial velocity

Thursday 21 March 2019 16:30 (15 minutes)

Author: Dr MAMAJEK, Eric (Jet Propulsion Laboratory)

Presenter: Dr MAMAJEK, Eric (Jet Propulsion Laboratory)