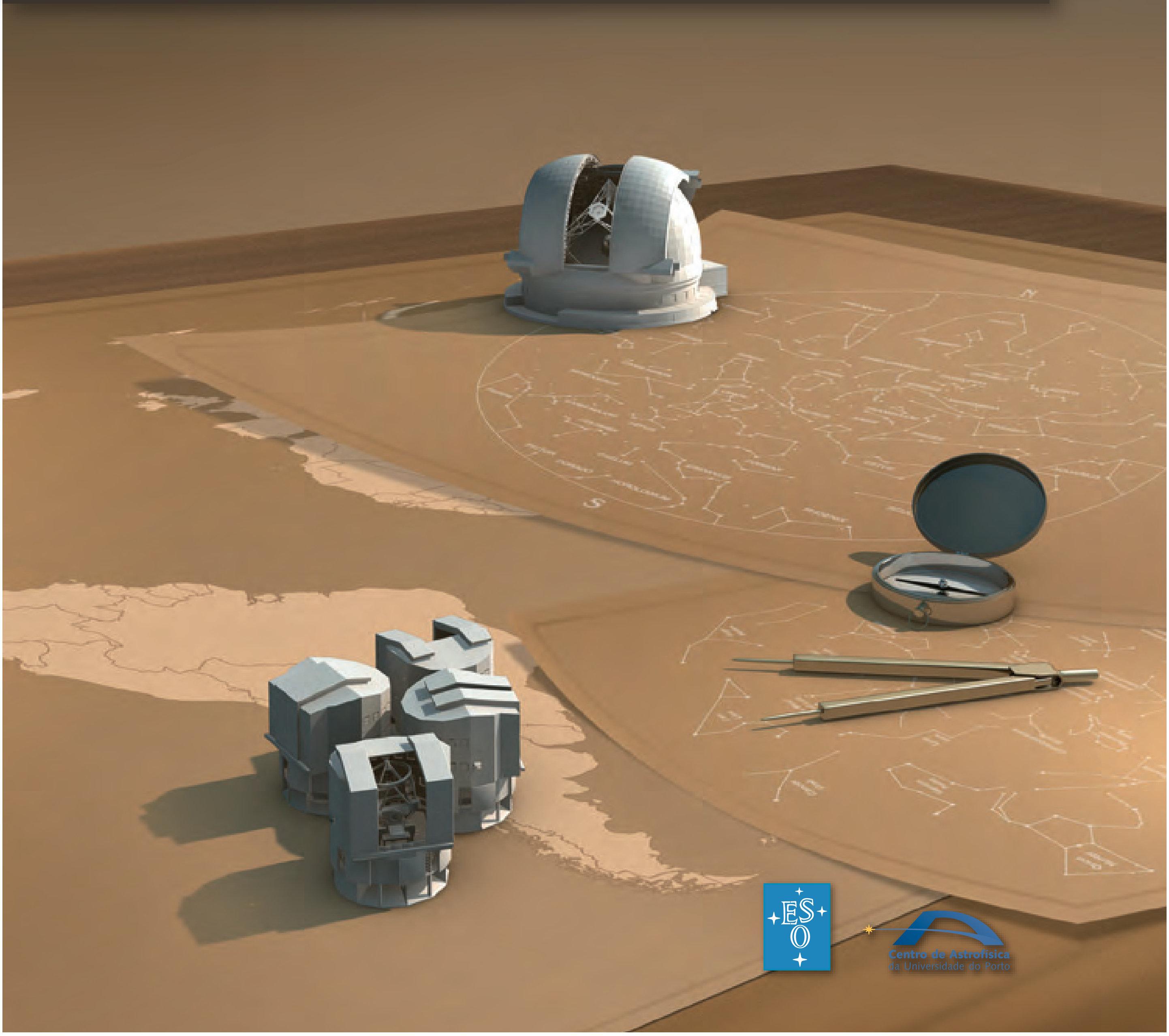
ABSTRACTS BOOK

An ESO-CAUP workshop on:

Towards Other Earths

Perspectives and limitations in the ELT era

19–23 October, 2009 | Porto, Portugal



Centro de Astrofísica da Universidade do Porto

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ESO

Centro de Astrofísica da Universidade do Porto

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An ESO-CAUP workshop on:

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Perspectives and limitations in the ELT era

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European Southern Observatory
Centro de Astrofísica da Universidade do Porto

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Review Talks (IR)

S. Udry
A. Collier Cameron
G. Chauvin
A. Udalski
D. Lin
Y. Alibert
M. Kissler-Patig
F. Pepe
S. Seager
G. Benedict

Invited Talks (IT)

X. Bonfils
T. Guillot
C. Marois
P. Kalas
L. Pasquini
N. C. Santos
H. Kjeldsen
U. Eriksson
E. Ford
D. Charbonneau
D. Lathan
G. Hebrad
J. Steffen
C. Cavarroc
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Conference Program

The meeting will have a duration of 5 days, starting on Monday morning and finishing on Friday around noon. The program is split in 3 large sessions. It includes Review talks (IR), Invited talks (IT) and a series of contributed talks. Review talks have a duration of 30+5 minutes, while invited and contributed talks have a duration of 20+5 and 12+3 minutes, respectively.

Sunday 18th

18:00-20:00 Registration Open/Welcome Cocktail (at CAUP)

Monday 19th

9:30 Welcome - Introduction

Session I: Current Results and Status on Prospects for Earth - Mass/Radius Planet Detection

9:45 S. Udry (IR) - *RV planet search around solar-type stars: The HARPS GTO legacy*

10:20 H. Jones - *Frequency of Low-mass Exoplanets*

10:35 A. Triaud- *Planetary orbit inclinations: the coming of a new diversity*

10:50 **Coffee Break and Poster View**

11:20 X. Bonfils (IT) - *GJ 581, the M dwarf forerunner*

11:45 P. Figueira - *Radial Velocities in the IR: prospects and issues from a first CRIRES campaign*

12:00 J. Bean - *The CRIRES Search for Planets Around the Lowest-Mass Stars*

12:15 **Lunch Break and Poster View**

13:45 A. Collier Cameron (IR) - *Current status of transit planet searches*

14:20 T. Guillot (IT) - *Probing the Interiors and Composition of Exoplanets*

14:45 S. Ballard - *A Hunt for Additional Planets in Known Exoplanet Systems with the NASA EPOXI Mission*

15:00 P. Nutzman - *Precise Transit Photometry coupled with Asteroseismology: Accurate Stellar and Planetary Properties for the Exoplanet System HD 17156*

15:15 **Coffee Break and Poster View**

15:45 C. Burke - *Ground Based Detection of Transiting Hot Earths*

16:00 G. Chauvin (IR)- *Direct imaging and current status of giant planet searches*

16:35 C. Marois (IT) - *Imaging Planets Orbiting other Stars: The HR8799 Multi-Planet System*

17:00 P. Kalas (IT) - *High-contrast optical imaging with HST: Direct detection of Jupiter and Kuiper Belt analogs around Fomalhaut*

17:25 G. Benedict (IR) - *Astrometry and Other Earths - Not Now, Probably Later*

18:00 **End of day 1**

Tuesday 20th

9:30 A. Udalski (IR) - *Current status of microlensing surveys*

10:05 D. Lin (IR) - *Current understading of Earth - mass planet formation*

10:40 E. Gaidos - *Cosmochemical considerations in the formation of Earth-like planets*

10:55 **Coffee Break and Poster View**

Session II: Astrophysical and Technical challenges and solutions towards the detection of other Earths

11:25 Y. Alibert (IR) - *Expected Harvest of planets*

12:00 M. Kissler-Patig (IR) - *ELT instrumentation for Earth like planet searches*

12:35 G. Serabyn - *Demonstrations of High-Contrast Phase Mask Coronagraphy in the ExAO Regime at Palomar*

12:50 **Lunch**

14:30 **Guided Tour**

Wednesday 21st

9:30 F. Pepe (IR) - *Technical limitations and solutions for cm/s RV precision*

10:05 A. M. Lagrange - *Detectability of Earth mass planets with RV technics around Sun-like stars*

10:20 L. Pasquini (IT) - *Wavelength calibration using the laser comb*

10:45 **Coffee Break and Poster View**

11:15 N. C. Santos (IT) - *Stellar activity and radial-velocities*

11:40 A. Reiners - *Detecting radial velocity variations in M dwarfs at infrared wavelengths: Achievable precision and the influence of starspots*

11:55 H. Kjeldsen (IT) - *Limitations imposed by low-amplitude stellar oscillations, granulation and activity*

12:20 **Lunch Break and Poster View**

14:00 U. Eriksson (IT) - *Limitations imposed by oscillations, granulations and activity mu - arcsec astrometry*

14:25 E. Ford (IT) - *Impact of Multiple-Planet Systems on Exoplanet Searches*

14:50 A. Correia - *Dynamics of Multi-Planet Extra-Solar Systems*

15:05 D. Charbonneau (IT) - *Ground - based Detection of Habitable Worlds: The Small Star Opportunity*

15:30 **Coffee Break and Poster View**

16:00 D. Latham (IT) - *NASA's Kepler Mission*

16:25 F. Bouchy/G. Hebrard (IT) - *Detection and follow - up of Earth - size exoplanet transiting candidates: Strategy, traps and results of the CoRoT mission*

16:50 F. Fressin - *Confirmation of transiting Super-Earth detections using Spitzer*

17:05 S. Aigrain - *Telluric planet detection in the presence of stellar activity: lessons from CoRoT*

17:20 J. Steffen (IT) - *The State of Transit Timing Variations*

17:45 N. Haghighipour - *Prospects of the Detection of Terrestrial Planets and Super-Earths via Transit Timing Variation Method*

18:00 **End of day 3**

Thursday 22nd

9:30 C. Cavarroc (IT) - *Theoretical limits for direct imaging*

9:55 E. Pantin (IT) - *Direct Imaging of Earth- and Jupiter- like planets in the thermal regime with ELTs*

10:20 S. Gladysz - *Telling exoplanets from speckles on ELTs*

10:35 M. Langlois - *Impact of calibration on extrasolar planets direct imaging with the Infrared Dual Imaging camera and Spectrograph for SPHERE*

10:50 **Coffee Break and Poster View**

11:20 P. Martinez - *Comparison of coronagraph for high-contrast imaging in the context of extremely large telescopes*

11:35 M. Mas - *The Self Coherent Camera : a new instrument for direct detection of exoplanets on an ELT*

11:50 M. Kasper/C. Verinaud - *EPICS, the exoplanet imager for the E-ELT*

12:05 **Lunch Break and Poster View**

14:15 H. M. Schmid - *Imaging polarimetry of extra-solar planets with the VLT and the E-ELT*

14:30 M. Tecza/F. Clarke - *HARMONI, the adaptive optics assisted optical and near-infrared integral field spectrograph for the E-ELT and its application for exoplanet research*

14:45 G. S. Salter - *High Contrast Observations with Slicer Based Integral Field Spectrographs*

Session III: Towards the characterization of Exo-Earths

15:00 S. Seager (IR) - *Exoplanet Atmospheres: From Discovery to Characterization and Beyond*

15:35 J. Christiansen - *Combining optical and infrared secondary eclipse measurements*

15:50 **Coffee Break and Poster View**

16:20 D. Deming (IT) - *Atmosphere detection via transits*

16:55 E. Pallé - *Characterizing the atmospheres of transiting rocky planets within the habitable zone*

17:10 N. B. Cowan - *Alien Maps of an Ocean-Bearing World*

17:25 **End of day 4**

20:00 **Conference Dinner**

Friday 23rd

9:30 V. Meadows/S. Seager (IT) - *Extrasolar Terrestrial Planet Characterization: Searching for Signs of Habitability and Life*

10:10 W. Traub (IT) - *Atmospheric Detection via Space-Based Direct Imaging*

10:35 M. Sterzik - *Search for Chiral Signatures in the Earthshine*

10:50 **Coffee Break and Poster View**

11:20 R. Galicher - *Polarimetry and spectral imaging of mature Jupiter and Super-Earth planets: SEE-COAST*

11:35 A. Hatzes (IT) - *The ExoPlanet Roadmap Advisory Team (EPRAT)*

12:00 V. Coude do Foresto (IT) - *Blue Dots*

12:25 S. Seager/S. Udry - *Concluding remarks*

13:00 **End of Meeting**

Session I

Current Results and Status on Prospects for Earth - Mass/Radius Planet Detection

RV planet search around solar-type stars: The HARPS GTO legacy

S. Udry[1], M. Mayor[1], C. Lovis[1], F. Pepe[1], D. Queloz[1], F. Bouchy[2] and the HARPS team

[1] *Geneva Observatory, Geneva University*
[2] *Institut d'Astrophysique de Paris*

Since a few years, high-precision radial-velocity measurements are unveiling a population of light planets with masses in the Neptune or super-Earth mass range. The emergence of this population is mainly due to the HARPS search for low-mass extrasolar planets targeting a few hundreds of G and K dwarfs of the solar neighbourhood, and which has been ongoing for more than 5.5 years on the ESO 3.6-m telescope as part of the HARPS GTO survey. The published low-mass planetary systems demonstrate the subm/s long-term stability reached by HARPS. As part of the HARPS GTO survey, a statistical volume-limited sample of solar-type stars has been followed as well at moderate precision (2-3 m/s).

A preliminary analysis of our data reveals the existence of a large population of low-mass ice giants and super-Earths predicted by numerical simulations of planet formation. We indeed detect several tens of candidates having minimum masses below 30 Earth masses, and orbital periods below 100 days. These numbers, although preliminary, indicate that about $30 \pm 10\,\%$ of solar-type stars may host such close-in, low-mass planets.

Some emerging properties of this low-mass population as e.g. the period, mass or host-star metallicity distributions, as well as the very high rate of multi-planet systems, will be discussed in comparison with equivalent properties of giant gaseous planets, taking advantage of the improvement of the statistics provided by new planet candidates of all types to be announced during the conference.

Frequency of Low-mass Exoplanets

H. Jones[1]

[1] *University of Hertfordshire*

We report first results from the Anglo-Australian Telescope Rocky Planet Search – an intensive, high-precision Doppler planet search targeting low-mass exoplanets in contiguous 48 night observing blocks. On this run we targeted 24 bright, nearby and intrinsically stable Sun-like stars selected from the Anglo-Australian Planet Search's main sample. These observations find HD 16417b, and confirm the detection of HD 4308b. Further, we have Monte-Carlo simulated the data from this run on a star-by-star basis to produce robust detection constraints. These simulations demonstrate clear differences in the exoplanet detectability functions from star to star due to differences in sampling, data quality and intrinsic stellar stability. They reinforce the importance of star-by-star simulation when interpreting the data from Doppler planet searches. The simulations indicate that for some of our target stars we are sensitive to close-orbiting planets as small as a few Earth masses. The two low-mass planets present in our 24 star sample indicate that the exoplanet minimum mass function at low masses is likely to be a flat $\alpha \sim -1$ (for $dN/dM \propto M^{\alpha}$) and that between 15±10% (at $\alpha = -0.3$) and 48±34% (at $\alpha = -1.3$) of stars host planets with orbital periods of less than 16 days and minimum masses greater than $3\,M_{\oplus}$.

Planetary orbit inclinations: the coming of a new diversity

Amaury H.M.J. Triaud[1], Didier Queloz[1], Andrew Collier-Cameron[2]

[1] *Observatoire Astronomique de l'Université de Genève*
[2] *School of Physics & Astronomy, University of St Andrews*

I will present new observations obtained with Harps. We measured specroscopically the transits of eight SuperWasp planets and detected the Rossiter-McLaughlin effect. This effect allows an estimation of the projected inclination of the orbital plane with respect to the stellar rotation. We increase by 50% the amount of available measurements of this angle and find that half of our stars are not coplanar.

Original models of planet formation had only one example to work with: our own solar system. With the discovery of planetary systems around other stars, a unsuspected diversity of mass, periods and eccentricity appeared changing our picture of the formation processes and their evolution and trying to create a more global theory. Transiting planets have brought a new diversity: the measurements of planetary radii show a large dispersion around simple models and most planets have been found to have a larger radius than expected. This presentation will show the coming of a new diversity: that of orbital inclinations prompting many questions on the formation of hot Jupiters and forcing us - again - to adjust our models in order to get - and stay - out of the plane.

GJ581 : the M dwarf forerunner

X. Bonfils[1,2] & HARPS Team[1,2]

[1] *Universit Joseph Fourier - Grenoble 1 / CNRS, laboratoire d'Astrophysique de Grenoble (LAOG)*
[2] *Observatoire de l'Université de Genève*

Our HARPS search for exoplanets around M dwarfs has unveiled several planetary systems. Among them GJ 581 is a planetary system that harbors four planets, including two super-Earths that straddle its habitable zone and a $m \sin i = 1.9$ $M_\oplus$ planet – the lowest-mass planet detected to date. Alone, GJ 581 makes the perfect illustration that M dwarfs are easier targets to search for low-mass and habitable planets.

Beyond the case of GJ 581, I shall discuss the status of our search program and its ability to populate the mass and temperature regime of habitable planets. I will also discuss the frequency of low-mass planets orbiting M dwarfs and how that statistic meshes up with planetary formation theory.

Radial Velocities in the IR: prospects and issues from a first CRIRES campaign

Pedro Figueira[1], Francesco Pepe[1], Claudio Melo[2], Nuno Santos[3], Christophe Lovis[1], Alain Smette[2], Stephane Udry[1]

[1] *Observatoire Astronomique de l'Université de Genève*
[2] *European Souther Observatory*
[3] *Centro de Astronomia e Astrofísica da Universidade do Porto*

With the advent of high-resolution near-IR spectrographs, radial velocity searches enter into a new domain. Advertised as the best way of observing the otherwise elusive M dwarfs, they are expected to pave the way towards other Earths. However, as of today, these spectrographs still struggle with calibration issues and deliver a much worse precision than state-of-the-art optical spectrographs such as HARPS.

In this work we present the results of our first campaign with CRIRES, mounted in ESO UT1, and exemplify how IR spectrographs can be used to reduce activity effects on radial-velocity measurements. We address calibration problems and some of the general challenges found along the way.

The CRIRES Search for Planets Around the Lowest-Mass Stars

Jacob Bean[1]

[1] *Institut für Astrophysik Göttingen*

M dwarfs are attractive targets for radial velocity planet searches aiming to find Earth-mass planets because lower-mass planets are more easily detected around lower-mass stars for a given level of observational precision. We are currently carrying out a search for planets around the lowest-mass M dwarfs using the CRIRES instrument at the VLT under the auspices of an ESO "Large Programme." We have developed, and are utilizing a new type of gas cell for obtaining high-precision radial velocities of late-type stars in the nIR spectral region. Observations in the nIR offer the advantages in that the targetted stars are bright enough for high-precision spectroscopy, and that the noise contribution from stellar activity is significantly reduced. I will present preliminary results from the project - in particular the work to obtain radial velocity precisions better than $10\,\mathrm{m\,s^{-1}}$ from nIR spectra. I will emphasize the lessons learned in the context of the next generation of nIR spectrographs specifically designed to detect Earth-mass planets around M dwarfs that are being considered for the E-ELT and other large telescopes.

Current status of transit planet searches

Andrew Collier Cameron[1]

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Ground-based transit searches using small-aperture, wide-field instruments account for 39 of the 63 transiting planets found to date. Indeed 7 of the 12 planets transiting stars brighter than $V = 10$ have been identified in this way. Immediate photometric and radial-velocity follow-up yields basic information such as orbital eccentricities and the mass-radius relation for close-orbiting gas-giant planets. Planets in close, eccentric orbits and massive planets in very close orbits constitute powerful probes of tidal energy dissipation in the planets and in their host stars. The brightest among them offer further valuable opportunities to characterise their dynamical histories and atmospheric properties. A small but significant population of planets with high orbital obliquities, and even some in retrograde orbits, appear to be the products of violent dynamical histories. The catalogues of bright hot Jupiters from these surveys will provide targets for infrared secondary-eclipse and phase modulation studies and atmospheric transmission spectroscopy well into the JWST/ELT era.

Probing the Interiors and Composition of Exoplanets

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With a steadily growing number of known transiting planets and the realisation that no less than 10,000,000 planets transit stars in our Galaxy alone, a lot is to be learned from the present discoveries and much more is to be expected for the future. The vast majority of transiting planets known today are gaseous giant planets. For them, a proper knowledge of their evolution is crucial because how they contract directly affects what we can infer on their composition. However, uncertainties abound: on the equations of state to be used, on the opacities in little known pressure-temperature regimes, and on physical processes themselves, in particular heat dissipation due to stellar tides. Taken individually, these uncertainties generally prevent from infering the planet's global composition. For example, some planets are found to be larger than possible for a hydrogen- helium planet of that age, mass and irradiation level when calculated with standard evolution models. However, by using the same hypotheses for all planets, it is then possible to infer model-dependent global planetary compositions and relate it to other observables. It is thus found that the "metallicity" of stars and that planets are correlated, giant planets orbiting close to very metal-rich stars being found to possess up to $\sim$ 100 Earth masses in heavy elements. I will discuss how further insight can be obtained from statistical models of the star and planet populations and their comparison to transiting surveys. I will finally present a few intringuing planets, in connection to the CoRoT mission.

A Hunt for Additional Planets in Known Exoplanet Systems with the NASA EPOXI Mission

Sarah Ballard[1], Jessie L. Christiansen[1], David Charbonneau[1], Drake Deming[2], Matthew J. Holman[1], Daniel Fabrycky[1], Michael F. A'Hearn[2], Richard K. Barry[3], Marc J. Kuchner[3], Timothy A. Livengood[3], Alfred Schultz[3], Tilak Hewagama[2], Jessica M. Sunshine[2], Dennis D. Wellnitz[2], Don L. Hampton[4], Carey M. Lisse[5], Sara Seager[6], and Joseph F. Veverka[7]

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The NASA EPOXI Mission monitored 7 known transiting exoplanet systems at high precision and rapid cadence for roughly 3 weeks per target. One of the primary goals of this investigation was to search for additional planets either directly through their photometric eclipses, or indirectly through the telltale variations induced on the times of transit of the known exoplanet. We present the first results from this study, focusing on the GJ 436 system for which the orbital eccentricity of the known planet hints at the presence of other bodies, and for which the small stellar radius permits planets as small as the Earth to be detected in transit. We present a refinement of system parameters for GJ 436 and upper limits on the putative planet GJ 436c.

Precise Transit Photometry coupled with Asteroseismology: Accurate Stellar and Planetary Properties for the Exoplanet System HD 17156

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For most transiting exoplanets, our knowledge of the planetary mass and radius is limited by uncertainties on the stellar parameters. While very observationally demanding, asteroseismology observations offer a precise and robust determination of stellar properties. We present results from a *Hubble* Fine Guidance Sensor program to measure stellar oscillations in the transiting planet host HD 17156. As part of this program we obtained precise photometry of three distinct transits of HD 17156b. Analysis of these transit light curves has enabled a major refinement in parameters for HD 17156b and also yielded three transit timings with a precision of 7 s. The transit and asteroseismology observations give independent measurements of the stellar density. Assuming the constraint on the mean stellar density from the asteroseismology as an input to the transit modeling yields a constraint on $(1-e^2)/(1+e\sin\omega)$ independently from radial velocity measurements. The coexistence of transit photometry and asteroseismology observations is an opportunity which may recur for many transiting planet systems discovered and observed by *Kepler*.

Ground Based Detection of Transiting Hot Earths

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Extrasolar planets that transit bright stars provide the opportunity to measure highly accurate planet radii and to detect and characterize planetary atmospheres outside the solar system. Transit and radial velocity surveys continue to push the envelope toward finding smaller planets. Is it possible to take advantage of the large primary mirrors on ground-based telescopes to detect or follow up Earth-sized transiting planets? I present results from an 8 night observing run on the WIYN 3.5m that surveyed the Hot Jupiter transiting planet stellar host XO-2 for an additional Earth-sized transiting planet. The achieved photometric precision is 250ppm/min on this V=11.2 star and is nearly at the scintillation, Poisson, and read noise limits. Based upon these results I will briefly discuss some limitations of the observations along with some possibilities for improvement. These observations do provide optimism that larger aperture ground based telescopes are not limited to discovery and follow up of Hot Earths orbiting M dwarf hosts, but can be extended to Hot Earth's orbiting bright solar type hosts as well.

Direct imaging and current status of giant planet searches

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With the development of high contrast imaging instruments and techniques, vast efforts have been devoted during the past decade to detect and characterize lighter, cooler and closer companions to nearby stars, and ultimately image new planetary systems. Complementary to other observing techniques (radial velocity, transit, micro-lensing, pulsar-timing and astrometry), this approach has opened a new astrophysical window to study the physical properties and the formation and evolution mechanisms of giant planets at orbits larger than 5 AU. Recent discoveries have unambiguously demonstrated the capabilities of such technique. In this review, I will briefly present the main motivations to use deep imaging to search for exoplanets and review the constant progress achieved thanks to imporved performances of advanced instrumentation and data analysis techniques. I will describe the main classes of stars identified and observed so far to increase the chances of detection. I will also detail the classical strategy adopted to identify false alarms and characterize true companions. I will review the current status of the different deep imaging surveys as well as the main results that recently led to the discovery of giant planets probably formed like the ones of our solar system. Finally, I will rise the questions and uncertainties related to the formation mechanisms, the physical properties and the frequency of these planetary mass companions to conclude with the exciting and attractive perspectives offered with the future generation of deep imaging instruments.

Imaging Planets Orbiting other Stars: The HR8799 Multi-Planet System

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Almost 15 years ago the first unambiguous direct detection of a substellar object around a star (Gl229B) was made. Several teams have since then pursued ambitious adaptive optics surveys on large telescopes, but only several brown dwarfs and a few possible candidate planets have been detected so far at generally wide ¿100 AU separations - it is unlikely that these have formed in a disk like the planets of our solar system and are probably the result of the binary star formation process. The essentially null result of these surveys, in contrast with the very successful radial velocity searches ¡5 AU, is suggesting that massive Jupiter-like planets are rare ¿20 AU around stars. The year 2008 marks then end of this long drought with the direct detection of planets around A-type stars. One of these discoveries, the HR8799 planetary system made at the Gemini North and Keck telescopes, is the first multi-planet system portrait and also the first direct detection of thermal emission of confirmed planets in orbit around a star. This system also shows convincing evidences that the three planets formed in a disk. The HR8799 system discovery marks an important step forward in the direct characterization of Jovians to Earth-like planets with future instrumentations and large ELTs. I will describe the HR8799 system discovery, new 2009 results and what we can expect in the near future with new generation adaptive optics systems and 30-m class telescopes. (ORAL/INVITED TALK)

High-contrast optical imaging with HST: Direct detection of Jupiter and Kuiper Belt analogs around Fomalhaut

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A direct imaging planet search using the optical coronagraph in HST's Advanced Camera for Surveys initially revealed a Kuiper Belt dust grain analog surrounding Fomalhaut that is offset from the star and cleanly sculpted at its inside border. Follow-up HST images further revealed a co-moving point source 18 AU interior to the dust belt with apparent orbital motion. I will discuss both the observational and theoretical evidence that the point source is a planet with < 3 Jupiter masses, making Fomalhaut b the lowest mass planet candidate detected via direct imaging. I will summarize alternate explanations for the optical brightness of Fomalhaut b, and discuss future plans for the detailed mapping of Fomalhaut's planetary system.

Astrometry and Other Earths - Not Now, Probably Later

G. Fritz Benedict[1] & Barbara E. McArthur[1]

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Unfortunately, not all companions transit their primary star. In the absence of such luck astrometry provides companion mass. This quantity is the fundamental parameter on which to base our models (or theories) of planetary formation and evolution. Statistical analyses of exoplanet systems which can be used to support theoretical models requires the actual masses, not just the minimum masses of exoplanetary systems. In this review I demonstrate that characterizing Jupiter-mass companions is difficult but possible with *HST*, show that there is a niche for ground-based astrometry to discover such objects orbiting very low-mass primaries, and argue that astrometric detection of Earth-mass planets around *nearby* stars requires micro second of arc per-observation astrometry. Hardware has achieved that (to an astrometrist) wince-inducing number, but for a platform (Space Interferometry Mission) not yet fully funded. Finally, I consider architecture. Are all exoplanetary systems coplanar? We should have a preliminary answer from *HST* shortly. By the end of the next decade *Gaia* will provide a robust answer, based on the characterization of hundreds of systems.

Current status of microlensing surveys

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During the last couple of years the planetary microlensing became a very important method of the detection of extrasolar planets. Due to the sensitivity to large range of exoplanet masses – down to Mars masses – and probing the regions of extrasolar planetary systems unavailable to other methods, the planetary microlensing already provided several important discoveries like a few low-mass cold super-Earths and a system being a rescaled copy of the Solar System.

Recent developments in the planetary microlensing field will be presented. Also the prospects for the new generation microlensing planetary surveys will be discussed.

Current understading of Earth - mass planet formation

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In the sequential-accretion scenario, progenitor embryos of solid planets form through dust grains condensation and sedimentation, planetesimals' runaway accretion, embryos' oligarchic growth, dynamical isolation, and chaotic coalescence through giant impacts after gas depletion. Earth-mass embryos can form at larger distances from their host stars in regions of the disk in which heavy elements are more easily assembled. In disks with modest or large surface densities, embryos formed interior to the snow line undergo inward Type I migration and congregate outside cavities cleared by the magnetospheres of their host stars. After disk gas depletion, embryos perturb each other, undergo orbit crossing, and coagulate into super-Earth through giant impacts. During the active disk accretion phase, the orbital decay of distant grains and embryos are stalled by a barrier near the snow line. As this barrier becomes less effective with the depletion of the disk gas, these icy embryos can resume their Type I migration and become super-Earths. These massive rocky planets will be the first population to be detected by radial velocity and transit surveys. It will soon be possible to delineate a population of ice-rock super-Earths from a population of iron-rock super-Earths with only the exoplanet radius distribution as observed. A super-Earth population dominated by ice worlds indicates that they emerged as failed cores beyond the ice line and subsequently migrated to within a few tenths of an AU of host stars during the epoch of gas depletion. A super-Earth population dominated by iron and rock worlds implies in situ assemblage of embryos which migrated to the stellar proximity in gas-rich disks and coagulated through giant impacts after gas depletion. Regardless of any assumption about composition, the observed orbital period distribution will help differentiate between and constrain the possible physical processes that terminate exoplanet migration.

Cosmochemical considerations in the formation of Earth-like planets

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Not all planetary systems are cut from the same cosmic cloth. The photospheres of main sequence stars record significant variation in the abundances of planet-forming elements and there may be other differences too subtle for us yet to perceive; models of galactic chemical evolution and the interstellar medium predict such variation (Prantzos 2007). Observations have already revealed a diversity of planetary masses and dynamics (Ford et al. 2003); variation in the composition of planet-forming disks will create profound differences in composition, evolutionary trajectories, and habitability even amongst planets of the same mass and at the same distance from their host star (Gaidos 2000).

High heavy element abundance (metallicity) of the star (primarily assessed by the proxy Fe) is strongly correlated with the presence of giant planets on short-period orbits where they can be detected by the radial velocity technique. The metallicity-planet correlation has been ascribed either to a common primordial state (Bond et al. 2008) or pollution of the photosphere (Li et al. 2009), but alternative views exist (Haywood 2009), and differences in the mass accretion rate of the circumstellar disk may affect both the growth of giant planet cores (perhaps preclusive of Earth-like planets) and metallicity (Gaidos 2009). The oberved variation in nebular accretion rate around young (T Tauri) stars will also result in large differences in the temperature structure of the disk and the position of the "snowline" which in turn may control the abundance of water in close-in planets (Gaidos & Raymond 2009). The abundance of water - the primary condensible of O - will affect the redox state of the nebula, as will the initial C/O ratio of the system, which is observed to vary from star to star and is predicted to evolve in the galaxy (Gaidos 2000).

Fe and Si are produced from different spectra of stellar progenitor masses and Fe/Si varies between stars, controlling the relative size of cores. Differences in the relative abundance of secondary constituents of silicate minerals, namely Mg, Na and K, can lead to large differences in the solidus (P,T conditions where melting starts) of rocky mantles of Earth-like planets (Hirschmann 2000); because melt production rates vary strongly with the location of the solidus, partial melting and crust production may cease early on Mg-rich and Na- and K-poor planets.

The long-lived radioisotopes U^{235}, U^{238}, Th^{232}, and K^{40} are thought to sustain mantle heat flow, convection, and geologic activity at the surface of the Earth over the past 4 Gyr (Turcotte & Schubert 1989). These are produced in massive stars and their abundance relative to the major (stable) elements will decrease with time as star formation rates decrease and metallicity increases. All else being equal, planets formed later will cease partial melting, volcanism, and replenishment of secondary atmospheres after a shorter interval of time (Kite et al. 2009).

Meteorites provide evidence for the presence of the short-lived radionuclide ^{26}Al in the early Solar System at an abundance sufficient to melt small planetesimals, and iron meteorites Hf-W ages constitute evidence that such melting did occur (Markowski et al. 2006). The thermal state of planetsimals may have affected how they accreted and were depleted in volatiles (Gaidos 2006, Gilmour 2008, Moskovitz 2009). If ^{26}Al was produced in massive stars and introduced into the molecular cloud through Wolf-Rayet winds and supernova, then the vast majority of protoplanetary systems will *not* contain ^{26}Al and the Solar System's initial value may be instead by typical of the non-zero minority (Gaidos et al. 2009). Our Solar System may represent only one small patch in the tapestry of planetary diversity.

Session II

Astrophysical and Technical challenges and solutions towards the detection of other Earths

Expected Harvest of planets

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In this talk, we discuss the future expected harvest of low mass planets, focussing in particular on present day and future transit missions such as CoRoT, Kepler and PLATO. Our estimations are based on a Monte-Carlo approach, which comprises different steps:

- in a first step, we use the population synthesis galactic model, also called the Besançon model, to derive the expected characteristics of stars in a given field, and derive the characteristics of expected target stars.
- in a second step, assuming the presence of a planet around every given star, we compute the transit detection probability, talking into account geometrical effects as well as instrumental effects for the different missions (mission duration, photometric noise, thershold signal-to-noise, etc...)
- in a last step, the follow-up efficiency for the same objects is calculated, taking into account the characteristics of the parent star (e.g. magnitude and variability) and different follow-up instruments, such as HARPS-NEF or ESPRESSO@VLT.

After a rapid comparison with the two first runs of CoRoT, we make predictions for Kepler and PLATO. Our calculations show that the radial velocity confirmation of Earth-like transit candidates will be quite difficult in the case of Kepler/HARPS-NEF, but not totally excluded around the brightest stars of the observed sample. In the case of PLATO/ESPRESSO, one can expect tens of Earth-mass planets in the habitable zone, detected in transit and further confirmed by radial velocity, and very large numbers of hotter and/or more massive planets.

ELT instrumentation for Earth-like Planet Searches

Markus Kissler-Patig[1]

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We will provide a brief overview of the three planed ELT projects: GMT, TMT and E-ELT and then focus on their current instrumentation plans with respect to Earth-like planet searches. We will look at instrumentation planed for radial velocity searches, but also for capabilities of transient searches and follow-up, as well as their ambitions for direct detections of exo-planets. We will also briefly provide an overview of the ELT instrumentation plans aimed at characterising atmospheres. We will discuss what the first generation of instruments might be capable of, and where upgrade paths might take us.

Demonstrations of High-Contrast Phase Mask Coronagraphy in the ExAO Regime at Palomar

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Phase mask coronagraphs provide both small inner working angles and high throughputs, and moreover, the vortex coronagraph is predicted to be able to provide close-to-ideal theoretical performance. This talk describes our recent work in developing phase mask coronagraphy and demonstrating its capabilities in the ExAO regime on our "well-corrected subaperture" at Palomar. Our 1.6 m diameter subaperture has already yielded detections of known brown dwarf companions at contrasts of a few thousand to one as close as 2.8 λ/D from their host stars, and debris disk structures to within 1.5 λ/D. Because of their great potential, we are now focusing specifically on vector vortex coronagraphic masks, in which an azimuthal phase spiral is generated by a rotationally symmetric half-wave plate. Our vortex masks already perform very well in the laboratory, with a demonstrated contrast at 3 λ/D of about a part in a million, and further improvements are planned to reach the rejection levels needed for terrestrial exoplanet detection.

Technical limitations and solutions for $\mathrm{cm\,s^{-1}}$ RV precision

F. Pepe, C. Lovis, B. Chazelas, P. Figueira, M. Mayor, D. Queloz, S. Udry, F. Wildi

Observatoire Astronomique de l'Université de Genève

The HARPS instrument has set a new benchmark in the measurement of precise radial velocities. Although the instrumental effects have been reduced by about a factor of 10 compared to the time preceding HARPS, the fundamental limit has not yet been reached. Some margin of improvement is possible and suitable in particular in view of new, challanging scientific objectives asking for higher instrumental performance and for the use of extremely large telescope. Enriched by the HARPS experience and motivated by the new challanges, we are continuously investigating present performance limitations and possible solutions to overcome them in future in order to reach $\mathrm{cm\,s^{-1}}$ precision. A review of our current knowledge and an outlook on future developments will be given in this talk.

Detectability of Earth mass planets with radial velocity technics around Sun-like stars.

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Using available data on the Sun, we have developped detailed simulations of the radial velocities, as well as other observables (bissector velocity span, photometry), of a Sun-like star surrounded by Earth mass planets located in the Habitable Zone, and observed with forthcoming generations of high precision spectrographs. We will present the results of the simulations and derive needs in terms of instrumantal performances and observing strategy.

Wavelength Calibration with Laser Frequency Combs

L.Pasquini [1]

[1] *ESO*

One fundamental ingredient to improve the precision of Radial Velocity (RV) measurements is the availability of a proper wavelength calibration source. All presently used sources suffer of serious limitations. Calibration systems based on Laser Frequency Combs (LFC) appear to be the ideal solution, able to fulfill all the astronomical requirements, and several groups in the world are actively pursuing their construction. Some of these combs have been tested with astronomical spectrographs, and our MPQ - ESO Collaboration has obtained very encouraging tests with the HARPS spectrograph at the 3.6m telescope at ESO, La Silla.

I will review the motivations, the principles, the development status and the perspectives of calibration systems based on LFC.

Stellar activity and radial-velocities

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The effects of stellar activity are known to be a threat to the measurement of precise radial-velocities in solar-type stars. In this talk we will discuss this effect in the detection of planets in the short (comparable to the rotational period of the star) and long period (comparable to the stellar magnetic cycle) regimes. We show that for low or moderately-active solar-type stars the effects of activity will not severely limit the detection of Earth-like planets using radial-velocity methods.

Detecting radial velocity variations in M dwarfs at infrared wavelengths: Achievable precision and the influence of starspots

Ansgar Reiners[1], Jacob Bean[1], Klaus Huber[2], Stefan Dreizler[1], Andreas Seifahrt[1]

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M dwarfs are of particular interest for the search for habitable planets because radial velocity variations are larger in low-mass stars, and because M dwarfs are the most numerous species of stars in the Galaxy. Unfortunately, M dwarfs are too faint for many planet search programs operating at optical wavelengths. Nevertheless, the first (habitable) planets around M dwarfs were found, and it is believed that many Earth-mass planets around M dwarfs can be detected in the near future, in particulay by applying the radial velocity technique to infrared wavelengths where M dwarfs emit the bulk of their energy. However, very little experience exists concerning the radial velocity technique at infrared wavelengths. Key assumptions for achieving the required precision in the infrared are 1) that M dwarfs exhibit enough spectral features, 2) that sufficient wavelength calibration can be provided, and 3) that activity-related radial velocity variations are small in the infrared. We have investigated each of these assumptions in detail, and we present our results on the achievable precision of radial velocity measurements in M dwarfs at infrared wavelengths.

Limitations imposed by low-amplitude stellar oscillations, granulation and activity

Hans Kjeldsen[1]

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Detection of any coherent periodic signal in a time series will be affected by noise and the presence of signals from other periodic phenomena (e.g. p-mode oscillations), granulation and spot activity. The signature of a planet in orbit around a given star show different properties than most noise sources and other periodic phenomena. Time series analysis techniques will be able to increase the SNR for a given planet signature, however some of those noise sources have amplitudes that will make it difficult to isolate the planet signal unless one is prepared to observe for extended periods (in some cases for many years). I will in the present talk review the relevant stellar noise sources, oscillations, granulation and activity and estimate how small a planet one may be able to detect for different types of stars. In the present talk I will concentrate on signals below the m/s level.

Limitations imposed by oscillations, granulations and activity μ–arcsec astrometry

U. Eriksson[1], L. Lindegren[2], ...

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To investigate the astrometric effects of stellar surface structures as a practical limitation to ultra-high-precision astrometry (e.g. in the context of exoplanet searches) and to quantify the expected effects in different regions of the HR-diagram. Stellar surface structures (spots, plages, granulation, non-radial oscillations) are likely to produce fluctuations in the integrated flux and radial velocity of the star, as well as a variation of the observed photocentre, i.e. astrometric jitter. We use theoretical considerations supported by Monte Carlo simulations (using a starspot model) to derive statistical relations between the corresponding astrometric, photometric, and radial velocity effects. Based on these relations, the more easily observed photometric and radial velocity variations can be used to predict the expected size of the astrometric jitter. Also the third moment of the brightness distribution, interferometrically observable as closure phase, contains information about the astrometric jitter. For most stellar types the astrometric jitter due to stellar surface structures is expected to be of the order of 10 micro-AU or greater. This is more than the astrometric displacement typically caused by an Earth-size exoplanet in the habitable zone, which is about 1–4 micro-AU for long-lived main-sequence stars. Only for stars with extremely low photometric variability (< 0.5 mmag) and low magnetic activity, comparable to that of the Sun, will the astrometric jitter be of the order of 1 micro-AU, sufficient to allow the astrometric detection of an Earth-sized planet in the habitable zone. While stellar surface structure may thus seriously impair the astrometric detection of small exoplanets, it has in general a negligible impact on the detection of large (Jupiter-size) planets and on the determination of stellar parallax and proper motion. From the starspot model we also conclude that the commonly used spot filling factor is not the most relevant parameter for quantifying the spottiness in terms of the resulting astrometric, photometric and radial velocity variations.

Impact of Multiple-Planet Systems on Exoplanet Searches

Eric B. Ford[1]

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Theoretical models of planet formation and observational results from Doppler planet surveys suggest that most planets reside in multiple-planet systems. As searches for extrasolar planets become more sensitive to planets with greater orbital periods and smaller masses, the fraction of known systems harboring multiple-planet systems will continue to increase. The radial velocity and astrometric signatures of multiple-planet systems can be complex and inevitably require a large number of model parameters. In some cases, the presence of additional planets can complicate the analysis of multiple-planet systems, make detection more challenging and/or increase the number of observations needed to characterize the masses and orbits of the planets in multiple-planet systems. At the same time, the detection and detailed characterization of such systems is extremely valuable for constraining models of planet formation and their dynamical evolution. I will discuss the challenges and opportunities that multiple-planet systems provide for planet searches using high-precision radial velocity, astrometric and/or transit observations. I will emphasize areas where interaction between observers and theorists can be expected to increase the yield and science return of upcoming planet searches.

Dynamics of Multi-Planet Extra-Solar Systems

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Stars with more than one planet are among the most interesting systems to be studied, as they resemble more to our Solar System and are very good candidates to host planets like the Earth. However, the exact orbital parameters of these systems are difficult to determine, since the radial velocities signatures overlap. In addition, sometimes the interactions between the planets are strong and the orbits deviate from the traditional Keplerian ellipses, in particular when mean motion resonances are present. Dynamical studies are then very important to fully understand and characterize these systems. The most striking example is the determination of the true masses of the planets, instead of the minimal ones. In this talk we present some techniques used to analyze those systems, illustrating with some real examples.

Ground-based Detection of Habitable Worlds: The Small Star Opportunity

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When exoplanets are observed to transit their parent stars, we are granted direct estimates of their masses and radii, and we can undertake studies of their atmospheres. As a result, such systems have profoundly impacted our understanding of the physics of exoplanets, yet to date only large exoplanets (akin to Jupiter or Neptune) are known to transit their parent stars. By targeting nearby M-dwarf stars, a ground-based transit search using modest equipment is capable of discovering planets as small as 2 Earth radii in their stellar habitable zones. Such a system would have an orbital period of roughly 10 days, present transits with a depth of 1%, be readily confirmed with current radial-velocity precision, and is 3 times more likely to be found in a transiting geometry than a habitable world orbiting a Sun-like star. The discovery of such planets is important for two reasons: First, they provide fundamental constraints on the physical structure of planets that are primarily rock and ice in composition. Second, by differencing spectra gathered when the planet is in view from those when it is occulted by the star, we can study the atmospheric chemistry of potentially habitable worlds. Such investigations will likely be feasible only for habitable worlds orbiting nearby M-dwarfs, for which the small stellar radius and low stellar luminosity boost the planet-to-star flux ratio to the level that can be studied with the James Webb Space Telescope.

NASA's Kepler Mission

David W. Latham[1]

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The Kepler Mission is designed to find true Earth analogs in the Habitable Zones of stars like the Sun. Kepler was launched on 6 March 2009 and is now observing 150,000 solar-type stars in a single field of view in Cygnus and Lyra that it will monitor for 3.5 years. The satellite is performing very well, and ground-based follow-up observations of transiting-planet candidates are underway at several observatories. Kepler will establish the frequency and characteristics of Earth-Like planets around Sun-like stars. The next step after Kepler will be an all-sky survey for the nearest and brightest transiting systems, to provide the best targets for future missions such as the James Webb Space Telescope.

Detection and follow-up of Earth-size exoplanets transiting candidates: Strategy, traps and results of the CoRoT mission

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The prime objective of the core planet-search program of the CoRoT space mission, started in 2007, is the detection of Neptune-like and rocky planets. Although the high-precision photometry obtained from space, the detection of planetary transits suffers some limitations from instrumental red noise and some ambiguities related to different kind of eclipsing systems which may produce transit events that perfectly mimic planetary transit. Radial velocity follow-up observations are therefore mandatory to establish or exclude the planetary nature of a CoRoT transiting companion as well as to accurately determine its true mass. The Doppler follow-up, based on high-resolution spectroscopy facilities, also suffers some limitations like early-type or giant stars, fast rotators, stellar activity, blended binaries, background moon light, instrumental effect at low Signal-to-Noise ratio. We present some elements of the strategy, traps, difficulties and results of the CoRoT mission and its Doppler follow-up devoted to the detection and characterization of small size transiting exoplanets.

Confirmation of transiting Super-Earth detections using Spitzer.

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The extremely interesting detection of transiting Super-Earth planets is now in range of Space surveys (CoRoT and Kepler), but is a very challenging case for confirmation by radial velocity facilities. The high photometric precision of CoRoT and Kepler allows to explore the range of blend scenarios that might fit the data equally well as a planet model. The expected astrometric precision of Kepler can potentially rule out many of the blends scenarios involving a background eclipsing systems, through the detection of the motion of the photocenter of the target. Most of the remaining blend scenarios for Kepler should thus involve hierarchical triple systems. In the latter cases, the additional constraint of a common distance for the blending star should enable to precisely model the scenario(s) that could mimic the light curve.

Unless the effective temperature of the contaminating star is virtually identical to that of the parent star (within 50 K), the depth of the photometric signal will be wavelength dependent. With its long wavelength bandpasses and high photometric precision, Spitzer is ideal to test this possibility, and potentially confirm the planetary nature of Super-Earth candidates. We present the results of our study of CoRoT-7b, the first such case, in two of Spitzer IRAC bandpasses, 4.5 and 8 microns.

Telluric planet detection in the presence of stellar activity: lessons from CoRoT

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Stellar activity induces both photometric variability and radial velocity jitter, and can thus affect the detection of small planets by both the transit and radial velocity methods. We have started a study using a sample of a few thousands of CoRoT light curves to evaluate both the detectability of planetary signals and the rate and nature of false alarms induced by stellar activity in transit and radial velocity searches for small planets, and will present preliminary results from this study, including:

- characterisation of the variability properties of CoRoT targets in terms of amplitude and dominant timescales, and discussion of emerging trends;
- evaluation of the detectability of different types of transits in the presence of the observed levels of variability, including those of terrestrial planets with relatively long periods
- simulation of RV jitter expected given the photometric variability, and exploration of the population of 'planets' one might expect to detect if the RV activity signal is interpreted as being of planetary origin.

The State of Transit Timing Variations

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I present a summary of the work done to date on the transit timing signal due to the presence of additional bodies in transiting systems. I also discuss the initial searches for the TTV effect as well as the prospects for planet discovery in the near future. Implications of TTV analysis for planet formation and evolution are discussed.

Prospects of the Detection of Terrestrial Planets and Super-Earths via Transit Timing Variation Method

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It is expected that many transiting extrasolar planetary systems host more and possibly smaller (e.g., terrestrial-class) objects. When in close-in orbits, these objects are potentially detectable via transit photometry of their host stars, or the measurements of the variations of the transit-timing of their close-in Jovian-mass planetary companions. The latter, also known as the TTV method, is particularly efficient in detecting small close-in planets in resonant orbits. The capability of this technique, i.e., the amplitude of the variations in the transit timing, is dependent upon the order of the resonance, the orbital elements and the masses of the planets, as well as the mass of the host star. To determine the connection between these quantities and the amplitude of TTV signals, we carried out an extensive study of transit timing in systems with different dynamical and physical properties, and calculated their TTV signals for large ranges of the values of their semimajor axes, eccentricities, and masses of their planets and central stars. Results indicate that variations in transit timing are largest if the perturbing and the transiting planets are in low-order mean-motion resonances. In that respect, we present the result of our large survey on the detectability of Trojan planets. To determine the prospect of the detection of terrestrial planets and Super-Earths, particularly in the habitable zone, we considered stars whose habitable zones are close to the transiting planet (namely M and K stars), and focused our attention on resonant periodic orbits. Results indicate that resonances such as 1:2 and 1:3 cause strong enhancements in TTV signals and present most probable configurations for the detection of habitable planets. We present the results of our simulations and discuss possible constraints that they may apply to the mass and orbital configuration of a detectable terrestrial-class object. We will also discuss the implications for the detection of such objects through continuous observations of known transiting planetary systems.

Theoretical limits for direct imaging

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The direct detection of Earth-like planets requires to achieve a contrast of 10^{-10} in visible and near-infrared at very small angular separations (a tenth of arcseconds). Several devices have been developped to meet these requirements. We focus here on the following system: a very well corrected wavefront (by extreme adaptive optics for instance) which feeds a coronagraph. This system being insufficient to detect telluric planets, a calibration device is also considered. We have developped an analytic model taking into account the different aberrations (residual aberrations from adpative optics, static aberrations) and the limitations induced by the instruments (coronagraph and calibration). Analytical results have been confirmed by numerical simulations.

Direct Imaging of Earth- and Jupiter- like planets in the thermal regime with ELTs

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The detection and the characterization of exoplanets will be one of the major topic for the astrophysical sciences in the next decade. In the context of the upcoming giant (30-42 m) ground-based telescopes (ELTs), it is important to assess the scientific perspectives for mid-infrared instruments observing in the L' (3.5 μm) to the N (8-13.5 μm) bands.
I will first show that to achieve the challenging goal of the direct imaging of the exoplanets in the thermal regime we will need to develop some new observing modes inherited from the high angular resolution techniques currently or soon used in the near-infrared range.
Besides the characterization of self-luminous giant exoplanets by direct imaging, we identify three important niches for the upcoming thermal infrared instruments on ELTs:

- the direct observations of warm (irradiated) giant exoplanets placed on relatively close orbits (0.2-1 AU)
- direct imaging of melted proto Earth-like planets at the young stages of the planets formation (10-100 Myr)
- potentially the first images of gaps generated by forming exoplanets in protoplanetary disks.

Telling exoplanets from speckles on ELTs

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Post-processing of images delivered by the eXtreme Adaptive Optics (XAO) instrumentation is a crucial step which can increase achievable contrast even by two orders of magnitude. Recently a new class of algorithms was proposed for the detection and first-order characterization of extrasolar planets from a sequence of adaptive-optics-corrected images. The algorithms are very suitable for ELTs which, with their large collecting area, allow for relatively short exposures.

In general, the methods discriminate between real sources and stellar PSF features based on statistics of recorded intensity. With multi-frame data one can compute parameters of intensity distributions in a data-cube. The parameters are chosen so that stellar light is suppressed while light from a companion is amplified. The methods, generally referred to as Stochastic Speckle Discrimination (SSD), are particularly useful in dealing with static speckles which are the greatest obstacle in detecting exoplanets.

We study several statistical metrics - from speckle contrast to the more complicated ones based on high order statistical moments. We demonstrate that different metrics provide different dynamic range, depending on initial image quality. Therefore each individual method could be matched to different ELT instrument.

The algorithms improved the reliability of detections in real data obtained with the Lick Observatory's 3m telescope, 5m telescope at the Palomar Observatory, and MMT Observatory's 6.5m telescope. Improvement is also very clear in results of recent experiments on the High-Order Testbench at ESO, as well as in simulated observations with the E-ELT.

Impact of calibration on extrasolar planets direct imaging with the Infrared Dual Imaging camera and Spectrograph for SPHERE

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The detection and characterization of extrasolar planets by direct imaging is becoming more and more promising with the preparation of dedicated high-contrast instruments and the help of new data analysis techniques. SPHERE (Spectro-Polarimetric High-contrast imager for Exoplanets REsearch) is currently being developed as part of the second generation instruments of the ESO-VLT. IRDIS, one of the SPHERE subsystems, will provide dual-band imaging with several filter pairs covering the near-infrared from 0.95 to 2.3 μm, among with other observing modes such as long slit spectroscopy. This paper describes the impact of instrumental calibration on finding and characterizing extrasolar planets, and on observing stratgies. It concludes by discussing simillar constraints for the upcoming generation of extremely large telescopes (ELTs) to achieve the required precision and stability.

Comparison of coronagraphs for high-contrast imaging in the context of Extremely Large Telescope

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We compare coronagraph concepts and investigate their behavior and suitability for planet-finder projects with Extremely Large Telescopes (ELTs, 30-42 meter class telescopes).

For this task, we analyzed the impact of major error sources that occur in a coronagraphic telescope (central obscuration, secondary support, low-order segment aberrations, segment reflectivity variations, pointing errors) for phase, amplitude, and interferometric type coronagraphs. This analysis was performed at two different levels of the detection process: under residual phase left uncorrected by an eXtreme Adaptive Optics system (XAO) for a wide range of Strehl ratios and after a general and simple model of speckle calibration, assuming common phase aberrations between the XAO and the coronagraph (static phase aberrations of the instrument) and non-common phase aberrations downstream of the coronagraph (differential aberrations provided by the calibration unit).

We derive critical parameters cope by each concept in order of importance and derive contrast level limitations. We show three coronagraph categories as function of the accessible angular separation and proposed optimal one in each case. Most of the time amplitude concepts appear more favorable, and the Apodized Pupil Lyot Coronagraph specifically gathers the adequate characteristics to be a baseline design for ELTs.

The Self Coherent Camera : a new instrument for direct detection of exoplanets on an ELT

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In order to detect Earth Like Planet, it is mandatory to reach a very high constrast and high angular resolution. In the framework of the instrument Exo-Planet Imaging Camera and Spectrograph (EPICS), which will be the planet finder of the future European Extremely Large Telescope (E-ELT), new instrumental concepts are necessary to improve the sensitivity of the telescope down to rocky planets.

While extreme adaptive optics and coronagraphy are mandatory to reach high contrast detection, the actual studies for future instruments such as SPHERE and GPI show that it is not enough. Indeed, the final detection in that case is limited by residual optical aberrations unseen by adaptive optics system. We propose a new instrument, the Self Coherent Camera (SCC), which can estimate and/or correct these residual errors directly from the science image. The SCC is based on the principle of light incoherence between star and its environment. This encoded signal can be used in two ways. On one hand, the estimation of wavefront errors is derived directly from the encoded speckles in the science image, avoiding differential errors due to beam separation and non common optics. On the other hand, since the planet signal is not encoded, we can extract photons of the planet from the residual stellar speckles.

To test this instrument in laboratory environment, we are setting up an optical bench. It combines high performance coronagraph (Four Quadrant Phase Mask coronagraph), a deformable mirror and the SCC itself. After recalling the principle of the SCC, we will present the expected perfomance of the SCC on EPICS, the status of the bench development and the preliminary results on both aspects : phase and amplitude estimation and the planet detection.

EPICS, the exoplanet imager for the E-ELT

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Dedicated instruments at large telescopes (SPHERE for the VLT, GPI for Gemini) are about to discover and explore self-luminous giant planets by direct imaging and spectroscopy. The next generation of 30m-40m ground-based telescopes, the Extremely Large Telescopes (ELTs), has the potential to dramatically enlarge the discovery space towards older giant planets seen in reflected light and ultimately even a small number of rocky planets. EPICS is a proposed instrument for the European ELT, dedicated to the detection and characterization of expolanets by direct imaging and spectroscopy. ESO launched a phase-A study for EPICS with a large European consortium which - by simulations and demonstration experiments - investigates state-of-the-art diffraction and speckle suppression techniques to deliver highest contrasts. The final result of the study early 2010 will be a conceptual design and a development plan for the instrument. We will present the EPICS concept and discuss its main challenges and science capabilities.

Imaging polarimetry of extra-solar planets with the VLT and the E-ELT

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Abstract: The future SPHERE VLT planet finder instrument includes a high precision polarimeter for the search and characterization of reflected and therefore polarized light from extra-solar planets. The EPICS planet finder study for the E-ELT considers a similar polarimetric mode with the aim to observe Earth-like planets around nearby stars.

This paper first discusses the expected polarization properties of extra-solar planets and the diagnostic potential of polarimetric observations. Then we describe the ZIMPOL polarimeter, which will be part of SPHERE. Performance simulations show that a contrast of 10^{-8} should be reachable with this instrument. With this sensitivity giant planets around the nearest stars could be detected in reflected light. Finally, we describe the technical challenges to be solved for EPICS / E-ELT for a successful detection of an Earth-like planet in reflected light with an imaging polarimeter.

HARMONI, the adaptive optics assisted optical and near-infrared integral field spectrograph for the E-ELT and its application for exoplanet research.

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HARMONI, the High Angular Resolution Monolithic Optical Near-infrared Integral field spectrograph, is a candidate first light instrument for the E-ELT intended to serve a wide range of science applications. For that purpose HARMONI provides different pixels scales ranging from diffraction limited 4 mas to 40 mas and spectral resolving powers from 4,000 to 20,000.

HARMONI will be equipped with a single conjugate adaptive optics wavefront sensor that together with the deformable quaternary E-ELT mirror will deliver near-diffraction limited image quality with on-axis Strehl ratios >75% for guide star magnitudes <8. Additionally, HARMONI will have a simple coronagraph implemented in its pre-optics. We will show performance predictions for the combination of coronagraph and high-order AO of HARMONI together with Spectral Deconvolution and HARMONI's potential in the field of exoplanet research.

HARMONI's capabilities enable medium contrast, spectroscopic follow-up observations of faint exoplanets detected with future planet finding instruments at 8 m telescopes, e.g. SPHERE at the VLT and GPI at Gemini, to characterise their stellar type, and physical properties such as age, mass, and temperature. Furthermore the high spectral resolutions offered by HARMONI enable unique spectroscopic studies that are otherwise not possible with SPHERE and EPICS. These exoplanets will be too faint to be characterised with instruments at 8 m telescopes, years before EPICS will be available at the E-ELT, making HARMONI the ideal instrument for follow-up spectroscopy.

High Contrast Observations with Slicer Based Integral Field Spectrographs

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All new direct detection instruments are now incorporating an Integral Field Spectrograph (IFS) due to their unique ability to both detect and characterise companions in a single observation thus obviating the need for expensive follow-ups. Using an IFS and a method called spectral deconvolution to eliminate quasi-static speckles we can achieve required contrasts by surpassing the limiting speckle noise
It has previously been thought that non common path errors in image slicer based IFSs would limit the achievable contrast by modifying the speckle pattern, however, our recent results with SINFONI(an instrument not designed for high contrast application) on the VLT has provided reason to doubt this.
As part of the EPICS(Exo-Planet Imaging Camera and Spectrograph on the E-ELT) design study an investigation has been made into whether slicer based integral field spectrographs do limit the achievable contrast as apposed to other IFU types and if so why and by how much.
We have a 2 pronged approach to tackle this question:

1. Simulation - By taking simulated complex amplitudes of a datacube, slicing it up in the spatial direction and adding appropriate WFE in the pupil plane we are simulating the effect an image slicer IFS has on the speckle pattern of a high contrast observation.

2. Experiment - These simulations will also be verified by an image slicer prototype on which we will create and track speckles as they move across slices at different wavelengths, letting us see how they are really being modified by the slicer based spectrograph

I will present results from the simulations and hope to also present the results from the experiment which is currently being assembled, ready for tests in August. The use of spectral deconvolution to eliminate speckles by using their chromatic behaviour will also be presented.

Session III

Towards the characterization of Exo-Earths

Exoplanet Atmospheres: From Discovery to Characterization and Beyond

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Fourteen years ago after the first discovery of exoplanets orbiting sun-like stars, few believed that exoplanet atmosphere observations were possible. Seven years ago, after the *Hubble Space Telescope* observation of the transiting HD 209458b atmosphere, many skeptics challenged it as a one-object, one-method success. With over two dozen exoplanet atmospheres observed today, we have solidly entered the first stage of exoplanet atmosphere research. I will review the highlights of hot Jupiter atmosphere studies: detection of molecular spectral features; constraints on atmospheric vertical structure; and diversity of day-night temperature gradients. I will show what we can robustly infer from the two best transiting hot Jupiter atmosphere data sets: HD 189733b and HD 209458b, using a new atmospheric temperature and abundance retrieval method. As hot Jupiter observations and interpretation are maturing, the next frontier is super Earth atmospheres. Theoretical models are moving forward with observational hopes pinned on the *James Webb Space Telescope*, scheduled for launch in 2014. Further in the future lies realistic attempts to answer the enigmatic and ancient question, "Are we alone?" via atmospheric biosignatures. Many of us are working hard to ensure we will have Earth analog targets for atmosphere observations in our life time. I will finish with a description of the lowest cost and nearest term chance we have for directly imaging Earth analog atmospheres: a space-based Terrestrial Planet Finder telescope that is a combination of the *James Webb Space Telescope* and a separately built and launched external occulter.

Combining optical and infrared secondary eclipse measurements

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The number of transiting planets with secondary eclipse measurements in various bandpasses is increasing rapidly. Measurements of infrared secondary eclipse depths with Spitzer has already led to the discovery of temperature inversions in extrasolar planet atmospheres, and upper limits on the optical secondary eclipse depths with MOST and EPOXI give us insight into the the atmospheric composition and global thermal properties. By combining the results, we can place constraints on the total planetary emission, and test for evidence that the planet is emitting more energy than it receives, as is the case for several solar system planets. Here we present new estimates of the secondary eclipse depths and timings of the exoplanet HAT-P-7b from Spitzer/IRAC and EPOXI, and undertake a combined analysis of these constraints on the models of the planetary atmosphere. In the coming year, observers will determine the optical and infrared phase curves of HAT-P-7 using Kepler and Spitzer, providing even more stringent constraints on the planetary energy budget and a direct study of the atmospheric dynamics.

Atmosphere Detection Via Transits

Drake Deming

Planetary Systems Laboratory, NASA's Goddard Space Flight Center

Transit techniques permit the direct detection of extrasolar planet atmospheres, and allow us to measure their temperature structure and composition, and infer their dynamical properties. Studies of transiting planets as small as Neptune have been successful using the Spitzer and Hubble Space Telescopes, and ground-based observers are now beginning to detect light from transiting exoplanets in the near-infrared. We have learned that the atmospheres of hot Jupiters are very dark at visible wavelengths, but emit copious amounts of infrared light. Although close-in giant planets should exhibit tidally-locked rotation, strong zonal winds redistribute absorbed stellar energy to produce hot nights on many of these worlds. The atmospheres of strongly-irradiated planets often exhibit temperatures rising with greater heights in their atmosphere. The physical cause of this inversion is believed to be a coupling between chemistry and strong visual absorption by certain species such as TiO and VO. Extension of transit studies to habitable super-Earths orbiting nearby M-dwarf stars will be feasible in the future using the James Webb Space Telescope. The degree of success for the transit technique applied to habitable super-Earths will be a reasonably strong function of the nature of their atmospheres.

Characterizing the atmospheres of transiting rocky planets within the habitable zone of M stars

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Recently we were able to retrieve the Earth's transmission spectrum trough lunar eclipse observations. This spectrum showed that the depth of most molecular species was stronger than models had anticipated. The presence of other atmospheric signatures, such as atmospheric dimers and Earth ionospheric absorption were also present in the spectrum. Here we present a semi-empirical approach that we have developed to estimate the likelihood of follow-up observations and atmospheric characterization of previously known transiting rocky planets. Visible and near-infrared medium-to-high resolution spectra of the in transit and out of transit star+planet system will be observed, and from their ratio measurements, the transmission spectrum of the planetary atmosphere will be obtained. Our simulations using the empirical Earth's transmission spectrum, and the observed stellar spectra for a variety of stellar types, indicate that the E-ELT will be capable of retrieving the transmission spectrum of an Earth-like planet around an M-star. This will require to co-add observations during several transits to a total of approximately 25 hours of in transit data (for late-Ms), plus another equal number of hours of out of transit data.

Alien Maps of an Ocean-Bearing World

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To simulate the kinds of observations that will eventually be obtained for exoplanets, the Deep Impact spacecraft obtained light curves of Earth at seven wavebands spanning 300-1000 nm as part of the EPOXI mission of opportunity. In this paper we analyze disc-integrated light curves, treating Earth as if it were an exoplanet, to determine if we can detect the presence of oceans and continents. We present two observations each spanning one day, taken at gibbous phases. The rotation of the planet leads to diurnal albedo variations of 15–30%, with the largest relative changes occuring at the reddest wavelengths. To characterize these variations in an unbiased manner we carry out a principal component analysis of the multi-band light curves; this analysis reveals that 98% of the diurnal color changes of Earth are due to only 2 dominant eigencolors. We use the time-variations of these two eigencolors to construct longitudinal maps of the Earth, treating it as a non-uniform Lambert sphere. We find that the spectral and spatial distributions of the eigencolors correspond to cloud-free continents and oceans; this despite the fact that our observations were taken on days with typical cloud cover. We also find that the near-infrared wavebands are particularly useful in distinguishing between land and water. Based on this experiment we conclude that it should be possible to infer the existence of water oceans on exoplanets with time-resolved broadband observations taken by a large space-based coronagraphic telescope.

Extrasolar Terrestrial Planet Characterization: Searching for Signs of Habitability and Life

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In the coming decades, the search for life outside our Solar System will be undertaken using astronomical telescopes and remote-sensing techniques to understand the photometric and spectroscopic properties of extrasolar terrestrial planets. To search for signs of surface habitability and life on distant planets, the most valuable data sets will likely be time-resolved photometry and spectra, which for unresolved exoplanets will be disk-integrated. To determine habitability, we must either directly detect large bodies of surface water, or attempt to constrain the surface temperature and pressure via a combination of observations and modeling. Spectroscopy will also be used to search for biosignatures, life's global scale effects on a planetary environment, which may manifest themselves as disequilibrium concentrations of gases in the atmosphere, characteristic wavelength dependent surface reflectivity or emissivity, or as temporal variability in planetary characteristics. To better guide future planet detection and characterization efforts, the NASA Astrobiology Institute's Virtual Planetary Laboratory Team uses planetary models to simulate extrasolar terrestrial planetary environments and spectra. These models can be used to explore planet-star interactions that affect habitability and the detectability of biosignatures, and to constrain the likely environments and remote-sensing characteristics of the inhabited Early Earth. The models can also be used to analyze Earthshine observations and spacecraft-obtained photometry and spectra of the disk-integrated Earth. We will summarize remote-sensing signs of habitability and life, on Earth and super Earths. We will illustrate our evolving understanding using recent results from both VPL and other models. We will discuss the best chance our community has to find and characterize true Earth-like planets in the next decade: using the *James Webb Space Telescope* combined with an external occulter.

Atmospheric Detection via Space-Based Direct Imaging

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Using our simulations of an early Earth and the present Earth, I will indicate which terrestrial exoplanet properties and signs of life can be observed, and how well, for a large coronagraphic telescope in space. I will compare this to the case of transits and ground-based characterization.

Search for Chiral Signatures in the Earthshine

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We search for circular polarization in the spectrum of the Earthshine as induced by chiral molecules of living material on the surface of the Earth. Biotic material with its helical molecular structure is known to produce circular polarization of reflected light up to levels of a few percent, thus in the range of detectability of FORS1 mounted at the Very Large Telescope in Paranal/Chile. Organic material on Earth is abundant, but its detectability using astronomical remote sensing techniques, e.g. through the Vegetation Red Edge, is challenging. Our experiment is a benchmark required for future attempts to detect biotic material on other astronomical objects. Preliminary results of the experiment show that circular polarization in the Earthshine is detectable, and may correlate with the fractional vegetation cover observed.

Polarimetry and spectral imaging of mature Jupiter and Super-Earth planets: SEE-COAST

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Spectral and polarimetric direct imaging is the best solution to measure physical parameters of exoplanets. Such detections require an ultrasmooth telescope and high dynamic range imaging devices involving efficient stellar suppression mechanism. Next generation of ground instruments ($2010-2011$) at the VLT (SPHERE) and on Gemini (GPI) are expected to provide spectra of young and massive Jupiter orbiting nearby stars ($< 10\,$pc) in near infrared light. In the same spectral range, one of the objectives of Extremely Large Telescope is the spectro-polarimetriy of Earth-like planets (2020). As for space missions, JWST (2015) will probably detect mature Jupiter-like planets in the $2-15\,\mu$m spectral range and several large space projects are planned to characterize Earth-like planets in more than a decade. However detection of Earths requires 10^{10} contrast very close to the hosting star (fraction of arcsec) and several spectral characteristics are very attractive in visible light. Direct imaging of giant planets and close-by super-Earth are then at the cross-road of a high scientific interest and a reasonable feasibility. We propose to use a $1.5-2\,$m telescope in visible light, the so-called SEE-COAST mission. We will present the scientific objectives of the mission and an overview of foreseen instruments.

The ExoPlanet Roadmap Advisory Team (EPRAT)

A. Hatzes[1], A. Boccaletti[2], R. Dvorak[3], M. Fridlund[4] G. Micela[5], A. Morbidelli[6], A. Quirrenbach[7], H. Rauer[8] F. Selsis[9], G. Tinetti[10], S. Udry[11], A. Anderson[12]

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[10] *University of College, UK*
[11] *Université de Genevé, Switzerland*
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ESA has established the Exo-Planet Roadmap Advisory Team (EPRAT) which is comprised of experts in the field of exoplanets from seven different European countries. The purpose of the EPRAT is "to recommend to the agency a roadmap leading to the long term goal of detecting biomarkers in Earth-like exoplanets in the habitable zone, and imaging such planets." The EPRAT will advise on the best scientific and technological roadmap to achieve this goal. As a first step in this consultation process ESA solicited White Papers from the community in Summer 2008. Over 20 White Papers were received covering a broad range of scientific and technical topics. I will summarize these White Papers and give an overview of the recent EPRAT activities.

Blue Dots

Vincent Coudé du Foresto[1] for the Blue Dots team

[1] *Observatoire de Paris – LESIA*

Blue Dots is a community-based initiative, involving more than 180 scientists (mostly from Europe, but also from the US, Japan and India and with observers from the main agencies) whose objective is to prepare a roadmap towards the detection and characterization of habitable exoplanets, recognizing that this ambitious goal will require several intermediate steps. The scope of the prospective is science oriented and not restricted to a particular detection technique. Its main finding and preliminary conclusions will be presented during this talk.

For more information visit the Blue Dots web site at http://www.blue-dots.net .

Posters

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Nr	Author(s)	Poster Title
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34	**M. Zechmeister, M. Küster**	*The generalised Lomb-Scargle periodogram (GLS) and the Keplerian periodogram*
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Planetary transit reconstruction in the presence of stellar activity

Aude Alapini[1], Suzanne Aigrain[1]

[1] *University of Exeter*

Accurately characterising exoplanets is important to constrain planet formation and evolution models. In our quest for higher precision photometry to find Earth-size planets, we are increasingly challenged by stellar activity whose level in most stars is larger than the signal from a small planet, as shown in recent CoRoT results. Efficient methods to separate intrinsic stellar signal and small planetary signal, without altering the latter, are becoming essential. We present a new Iterative Reconstruction Filter (IRF) which recovers the signals at the orbital period of the planet and improves the estimate of the planet parameters on average. We apply the IRF to the CoRoT space photometry of the stars known to harbour planets in an attempt to refine the planet parameters and search for secondary eclipses and orbital phase variations.

The chromospheric activity of FGK stars in the solar neighborhood as an estimation of the radial velocity jitter

D. Montes [1], R. M. Martínez-Arnáiz[1], J. Maldonado[2], C. Eiroa[2], et al.

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We present here some of the results of our ongoing long-term high resolution spectroscopic study of nearby (d $<$ 25 pc) FGK stars which aim is to characterize the local properties of the Galaxy, in particular the star-formation history. The level of chromospheric activity of these stars have been determined using different activity indicators, such as Hα, Ca II H&K lines or Ca II IRT lines.The chromospheric contribution has been determined using the spectral substraction technique. The $R_{\rm HK}$ index determined from the Ca II H&K fluxes determined in this way has been compared with the tradicional $R'_{\rm HK}$ index (derive from the Mount Wilson S index) and calibrated with the $R_{\rm H\alpha}$ and $R_{\rm CaIRT}$ derived from our spectra. We have used these chromospheric activity indexes to estimate the range of expected radial velocity jitter (σ_{rv}) of these stars using empirical relationships, given by others authors, between σ_{rv} and $R'_{\rm HK}$. These values provide an estimation of the activity related noise one should expect for a star, and thus to set the minimun detectable mass for a planet orbiting the star or determine the minimal amplitude variation that could be suspected to be a planet. Following this idea the data presents an enormous potential in terms of target selection for exoplanet searches surveys.

Stellar wobble caused by different gravitational sources

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[1] *Departamento de Física da Universidade de Aveiro*
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We will present recent work where we investigate the effect of a binary system on a star's centre of mass motion. We will show that although this effect can at first sight be mistaken by a planet companion to the star, more accurate observations should allow us to discard this possibility. We will also present new results concerning other triple system's configurations.

Stellar limitation in the search and characterization for exoplanets

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Most active stars have been rejected from major radial-velocity surveys due to the noise induced by photospheric luminosity variations. Now, they cannot continue to avoid these targets because instruments like CoRoT or Kepler that need radial-velocity follow-up found planets around active stars. We monitored two active planetary host stars: HD189733 with the SOPHIE (OHP, France) spectrograph and IotaHor with HARPS (ESO, La Silla, Chile). We used all the parameters available from high-precision spectroscopic measurements to provide a means of disentangling RV variations due to Doppler motion from the noise induced by stellar activity.

On the stellar activity cycles and radial velocity variations: implications for exoplanet search programs

J. da Silva[1,2], N. C. Santos[1], C. Melo[3], C. Lovis[4]

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The ever increasing level of precision achieved by radial-velocity instruments is opening the way to the discovery of very low mass and long period planets, identical to the Solar System giants. These systems will be detectable as low amplitude signals in radial-velocity. However, an important obstacle to their detection may be the existence of stellar magnetic cycles with similar timescales.

Here we present our first results of a long-term project where we used the spectra of a sample of 8 solar-type stars with well known chromospheric activity cycles. The aim was to enquire if these magnetic cycles can induce stellar radial-velocity variations and if these variations can be distinguished from the signal produced by a real long-period planetary companion. The spectra were obtained with the HARPS spectrograph (ESO, Chile) over the course of 5 years. This data was used to 1) derive the activity level of the star at each date using different spectroscopic indices, and 2) search the data for possible correlations between the different chromospheric indices, the radial-velocities, and the bisector inverse slope.

Long Term Activity in dM Stars

Pablo Mauas[1], Andrea Buccino[1], Rodrigo Díaz[1,2], Carolina von Essen[3]

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M dwarf stars, due to their low mass, are natural targets to search for Earth-like planets. Furthermore, it has recently been recognized that terrestrial-type planets orbiting dM stars in the liquid-water habitable zones can be suitable places for the emergence and evolution of life. However, dM stars can be very active, giving rise to large flares. Unfortunately, due to their low intrinsic brightness, these stars are not usually the target of long-term observational studies of stellar activity, and therefore their long-term variability is usually not known.

A decade ago we started one such long-term program, to obtain spectra of a number of stars, with special interest in dM stars. These observations allowed us to find periods in two such stars (Prox Cen and Gl 375). Here we report our results on other dM stars, combining our spectroscopic observations with photometric data.

Stellar noise and Planet detection

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Using HARPS asteroseismology measurements for G2, G8 and K1 dwarfs, we created noise models for these stars, including 4 types of noise:granulation, oscillation, photon and instrumental noise. The activity noise, calculated by simulation of Sun-like spots on a rotating star, as been added to these models. With the final noise models, we can predict the improvement made by further spectrographs such as ESPRESSO. Using the BERN exoplanet population and our noise models, we are able to calculate, for this new instrument, the mass detection limit as a function of the period, as well as the proportion of exoplanet that would be found. According to this work, the main achievement of ESPRESSO will be the possibility to detect planets of 1 to 2 Earth mass in the habitable zone of K dwarfs such as $\alpha\, Cen\, B$.

Study of optical fibers scrambling to improve radial velocity measurements

Bruno Chazelas[1], Francesco Pepe[1],Franois Wildi[1],Franois Bouchy[2], ...

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The detection of extrasolar planets has been possible first thanks to the use of radial velocity (RV) measurements. This technique has accomplished extraordinary achievements and pushed the planet detection limits down to super-earths. The current precision achieved by RV is around 30 $cm.s^{-1}$. To reach the required precision to detect earth-like planets it is necessary to reach precision of the $cm.s^{-1}$. To rachieve this it is necessary to address astrophysical issues like intrinsic radial velocity noise due to stellar activity but it is also necessary to address some instrumental challenges, in particular in the stability domain, which is one essential element off the RV technique. This poster shows possible improvements in the image scrambling performed by optical fiber necessary to mitigate the effects of atmospheric turbulence and telescope guiding errors. Current state of the art instrument still suffer from residual fluctuations in their illumination : either in the slit space or in the pupil space. This produces direct shifts or in chromatic deformations of the spectrum that results in systematic errors on the RV measurement. We present an analysis of present performances of circular step index fibers and the properties of square and octogonal optical fibers, through simulations and lab experiments, that could improve significantly the scrambling performances of RV instruments.

EPICS: the extrasolar planet finder of E-ELT
Science drivers and perspectives

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In the last few years many efforts have been done toward the development of dedicated instruments for the direct detection of exoplanets. Next generation facilities for large telescopes (SPHERE for the VLT, GPI for Gemini) are expected to explore the outern regions of young exoplanetary systems, searching for self-luminous giant planets, providing complementary informations with respect to the indirect methods which lead to most of the discoveries up to now. With the next generation of 30m-40m ground-based telescopes, the Extremely Large Telescopes (ELTs), the capabilities of these "planet-finders" will dramatically rise, towards older giant planets seen in reflected light and ultimately even a small number of rocky planets. EPICS, the proposed instrument for the European ELT, surely fits in this framework, having as a science goal the detection and characterization of exoplanets by direct imaging and spectroscopy. In this talk we will briefly present the drivers of the EPICS science case, together with the results of our prediction of its capabilities, both in terms of number of detections and characteristics of the planetary systems that EPICS will explore.

Probing atmospheric lines stability with HARPS

Pedro Figueira[1], Francesco Pepe[1], Christophe Lovis[1]

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The usage of a precise wavelength reference is paramount to many astronomical purposes, one of which being radial velocity studies. Unlike the Th-Ar lamp or the I_2 gas cell, some other current methods have not been intensively used and lack a proper characterization.

In particular, the ultimate stability of the absorption lines originated in our atmosphere is still largely unknown. We present the first results from our on-going study on atmospheric lines using HARPS. The very high intrinsic precision of HARPS (lower than 1 m/s) provides for a very stable background against which the lines' stability can be measured. We analyze the radial-velocity behavior of the O_2 lines present in our atmosphere and assign possible causes for the detected variations.

Atmospheric Properties of Palandöken Mount

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Paladöken Mount has a location next to the Erzurum city, and is amongst the highest peaks of Turkey with its 3175 meters altitude. It currently serves as a famous ski-center in the country. However, it may provide a good observing site for optical + infrared observations with its clear and dark skies.

We present the preliminary results based on a meteorological station and a DIMM (Differential Image Motion Monitor) equipment stand on the summit. The first meteorological and seeing data collected respectively for one year and few months promise that the site has good observational conditions for optical and IR observations.

Detection and characterization of extrasolar planets with extreme adaptive optics on the E-ELT

Szymon Gladysz[1], Bruno Femenia Castella[2], Markus Kissler-Patig[1], Rafael Rebolo Lopez[2], Laurent Jolissaint[3]

[1] *European Southern Observatory*
[2] *Instituto de Astrofisica de Canarias*
[3] *Leiden Observatory*

The European Extremely Large Telescope (E-ELT) with its diameter of 42m will provide the astronomers with unparalleled sensitivity to faint sources. Yet, in order to exploit its diffraction limit which is a dominant factor in direct imaging of exoplanets, one has to use extreme adaptive optics (XAO). We model the performance of first- and second-generation XAO systems on the E-ELT. We also present two most promising techniques which increase the achievable contrast by two orders of magnitude: spectral deconvolution applied to spectroscopic data, and differential polarimetry. We discuss how the contrast delivered by the XAO instruments and techniques translates to the detectability of various classes of exoplanets. The accuracy of estimation of exoplanetary spectra is also discussed.

Integral Field Spectroscopy & Spectral Deconvolution: on-sky results with SINFONI

N. Thatte[1], R. Abuter[2], E. Nielsen[3], F. Clarke[1], M. Tecza [1], G. Salter[1], L. Close[3].

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The technique of spectral deconvolution (Sparks & Ford 2002), which uses the lambda dependence of speckles (speckle chromaticity) to identify and eliminate quasi-static speckles (super-speckles) from high contrast data cubes, promises to bring enormous gains in sensitivity. The homogeneous data cube required for application of spectral deconvolution to ground based data requires adaptive optics assisted integral field spectroscopic data. However, to date, no integral field spectrograph optimized to obtain such data sets is delivering on-sky data.

We have been using the SINFONI IFS at the VLT over the last few years to achieve high contrast imaging spectroscopy using spectral deconvolution techniques. Here, we report on our recent results, including high contrast spectra of AB Dor C, 2MASS1207b, etc. We also report on plans to add a simple coronagraphic mode to SINFONI.

A Fabry-Perot interferometer for the wavelength calibration of radial velocity spectrographs

François Wildi[1], Gaspare Lo Curto[2], Bruno Chazelas[1], Christophe Lovis[1], Francesco Pepe[1], Stephane Udry[1]

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[2] *ESO Garching*

To complement and possibly improve the wavelength calibration performed on radial velocity spectrographs with the Thorium-Argon (Th-Ar) discharge lamps, the Observatory of Geneva has designed and built a calibrator system based on a Fabry-Perot interferometer. Unlike the Th-Ar lamp this device allows the production of optimally and regularly spaced (in frequency space) calibration lines covering all orders of the spectrograph. Our poster will review the design of the calibrator as well as the results obtained during its 1st commissioning run on HARPS in Sept 2009

CRIRES cross-dispersed; a step towards sensitive IR searches for red stars hosting planets?

Hans Ulrich Käufl[1], Paul Bristow[1], Bernhard Delabre[1]

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CRIRES is an infrared high resolution spectrograph at the VLT. It was designed as a pre-dispersed long slit spectrograph. While it could be proven, that radial velocity (RV) measurements with a precision of 10-20m/s are possible, CRIRES does not lend itself easily for a systematic RV search campain. Indeed, so far CRIRES has not detected any planet, but it has destroyed one, when it could be demonstrated, that in the case of TW-Hya the apparent optical RV-signal was indeed due to a star spot. Still radial velocity searches in the near-IR are highly desirable. In preparation for a CRIRES upgrade the idea to add limited cross dispersion has surfaced. A full-fledged implementation, however, appears not realistic. Limited cross dispersion (e.g. three orders instead of one) appears relatively easy. The options will be presented and a discussion as to the various trade-offs should be initiated.

Coudé Train Concept Analysis for the VLT Spectrograph in the ESPRESSO project

Alexandre Cabral[1], João Coelho[1], Nuno C. Santos[2], José Rebordão[1], André Moitinho[3], António Amorim[3], Jorge Lima[3], Denis Mègevand[4], José-Miguel Herreros[5], Paolo Di Marcantonio[6], Christophe Lovis[4], Francesco Pepe[4], Maria-Rosa Osorio[5], Stefano Cristiano[6]

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Being the first purpose of ESPRESSO to develop a competitive, innovative high-resolution spectrograph to fully exploit the VLT potentiality and to allow new science, it is important to develop the VLT array concept bearing in mind the need to obtain the highest stability, while preserving an excellent efficiency. This high-resolution ultra-stable spectrograph will be installed in the VLT at the Combined Coud Laboratory (CCL) fed by a Coud Train (CT) which brings the light from the Nasmyth platforms to the CCL, where it feeds the spectrograph. Several concepts can be envisaged for the CT depending on the use of mirrors and lenses or fibers or any of the possible combinations of them. The different concepts will have different characteristics in terms of efficiency, stability, complexity, cost, etc. In this paper we present the alternative concepts being considered and the efficiency and complexity analysis of each of them. A balance between the three main concepts is also presented.

ESPRESSO, a rocky exoplanet searcher for the VLT

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ESPRESSO is a new high resolution, highly stable spectrograph for the VLT. It will inherit and enhance most capabilities from HARPS and UVES, combining both stability and efficiency. The main science driver will be the detection and characterization of Earth-like planets, but many additional science cases will benefit from its highly stable spectroscopic observations.

The facility will be installed at the combined Coudé focus of the VLT and may be linked to any of the four UT telescopes, enabling thus a great flexibility for the efficient use of telescope time. Furthermore, it will be able to combine all the four UT's light incoherently in a lower resolution mode. ESPRESSO will thus be the first instrument worldwide installed on the equivalent of a 16-meter class telescope.

The ESPRESSO consortium is composed of Italian, Portuguese, Spanish and Swiss institutes. Currently in Phase A, the project will enter the detailed design phase in summer 2010. Installation and commissioning on the VLT is foreseen by end of 2014.

Exoplanet host stars in young moving groups

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We present a detailed study of the kinematics of exoplanets host stars (exoplanet.eu) with known parallactic distance and precise proper motion and radial velocity measurements, from where the Galactic space motions (U, V, W) were computed. For the stars with U and V velocity components inside or near the boundaries that determine the young disc population as defined by Eggen, we analysed the possible membership in the classical moving groups with ages between 10 and 600 Ma (e.g. Local Association, Castor, Ursa Majoris, IC 2391, Hyades) and the recently identified young nearby loose associations with ages younger than the Pleiades (e.g. β Pictoris, Tucana-Horologium). For the candidate members in young stellar kinematic groups, we compiled the information available in the literature in order to constraint their actual youth by applying age-dating methods for late-type stars, such as lithium abundances, chromospheric and coronal emissions, colour-magnitude diagrams and pre-main sequence isochrones. We identified several dozens young exoplanet host star candidates, many of which were considered to have solar-like ages.

Asteroseismic Determination of the Inclination Angle of a Solar-Like Star: How can SONG help us?

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Asteroseismology provides us with a real possibility of extracting the inclination angle, i, between the direction of the rotation axis of a solar-like star and the line of sight. In fact, the acoustic power spectrum of a solar-like star carries the signature of its inclination angle, translated into the relative visibilities of the components of low-degree non-radial oscillation modes. A very interesting prospect arises, to be specific, that of conducting ground-based surveys of bright targets ($0 \leq V \lesssim 6$) in order to firmly select a number of stars for which the likelihood of a transit detection is enhanced, i.e. stars for which $i \gtrsim 80°$.

That has been the main motivation for the current study, which was conducted from a SONG network's perspective. Briefly, SONG (Stellar Observations Network Group) is a Denmark-based initiative that aims at creating a global network of highly specialized 1 m-telescopes dedicated to the study of phenomena occurring in the time domain. Asteroseismic studies with SONG will be performed through spectroscopic measurements of stellar oscillations, which have two main advantages relatively to intensity observations, namely an enhanced spatial resolution and a decreased sensitivity to the stellar background.

We have carried out a series of Monte Carlo simulations in order to assess the accuracy and precision in determining i, doing so for stars with several surface rotation rates ($\Omega_\odot \lesssim \Omega \leq 6\,\Omega_\odot$) and considering different total observing times ($T = 30, 60, 120\,\mathrm{d}$). Furthermore, the effect of the window function has been taken into account.

Terrestrial planet signatures in the chemical composition of stars

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Studies of extra-solar planetary systems and the possibility of life in the Universe depend fundamentally on whether the Sun and its planets are typical. Previous studies have concluded that the Sun is a typical star as regards its chemical composition, but this may be due to the relatively high (∼0.05 dex) abundance uncertainties in typical abundance studies. We have conducted an elemental abundance analysis of unprecedented accuracy ($\sigma \sim 0.01$ dex) to show that the Sun shows a characteristic signature of dust condensation with a ∼20% depletion of refractory elements relative to the volatile elements in comparison with solar twins and solar analogs known to have close-in giant planets. The abundance differences correlate strongly with the condensation temperatures for the elements. We propose that the differences in abundance patterns are related to the formation of planetary systems like our own.

Automatic determination of precise spectroscopic stellar parameters in planet search samples

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The precise determination of spectroscopic stellar parameters is very important for several areas of stellar astrophysics. This task is usually very time consuming and since it is normally based on interactive routines it takes much of the attention of the person that is deriving such parameters. Moreover the amount of data coming from the high-resolution spectrographs currently available for the community (e.g. HARPS and UVES, from ESO) is rising in a away that we cannot sustain their data analysis on the same rate with the current procedures.

In order to keep up with this rate that will increase even more with the upcoming new generation instruments such as ESPRESSO, we need to start using automatic and faster procedures in order to derive precise parameters. This automatic procedure can be included in the pipeline of such instruments after the data reduction. Using on-time derived stellar parameters can be very helpful for the observing strategy of several observing programs.

We will present some automatic tools in development such as ARES that can be used for this purpose.

BP Psc - a laboratory for planet formation and disruption

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The dusty-disk embedded star BP Psc was until recently thought to be a very young object, but there are indications that the dusty disk is due to disruption of a close companion, possibly a hot Jupiter, and that the star itself is evolved. We will present recent HARPS observations and discuss how this object may be used as a laboratory for disruption and re-creation of planets.

Chemical abundances of 451 stars from the HARPS GTO planet search program
Thin disc, thick disc, and planets

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We present a uniform study of the chemical abundances of 12 elements (Si, Ca, Sc, Ti, V, Cr, Mn, Co, Ni, Na, Mg, and Al) derived from the spectra of 451 stars observed as part of one of the HARPS GTO planet search programs. Sixty eight of these are planet-bearing stars. The main goals of our work are: i) the investigation of possible differences between the abundances of stars with and without planets; ii) the study of the possible differences in the abundances of stars in the thin and the thick disc. We confirm that there is a systematically higher metallicity in planet host stars, when compared to non planet-hosts, common to all studied species. We also found that there is no difference in the galactic chemical evolution trends of the stars with and without planets. Stars that harbour planetary companions simply appear to be in the high metallicity tail of the distribution. We also confirm that Neptunian and super-Earth class planets may be easier to find at lower metallicities. A statistically significative abundance difference between stars of the thin and the thick disc was found for [Fe/H]<0. However, the populations from the thick and the thin disc cannot be clearly separated.

CARMENES: Calar Alto high-Resolution search for M dwarfs with Exo-earths with a Near-infrared Echelle Spectrograph

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CARMENES is a study for a next-generation instrument for the 3.5 m telescope at the Calar Alto Observatory that will be built by an international consortium. CARMENES stands for *Calar Alto high-Resolution search for M dwarfs with Exo-earths with a Near-infrared Echelle Spectrograph.* Since M dwarfs have low effective temperatures ($T_{\rm eff} < 4000\,{\rm K}$), our spectrograph is designed to operate in the optical red and the near infrared, where they emit the bulk of their radiation. High thermal and mechanical stability and a suitable wavelength calibration strategy are needed to reach radial velocity accuracies of a few meters per second, which are necessary to detect exoplanets of only a few Earth masses within the habitable zones of such cool, low-mass stars. We also aim to search for gaseous planets in orbit to K giants and to use asteroseismology to refine the parameters of planet host stars. The target radial velocities will be monitored with a fibre-fed cross-dispersed echelle spectrograph with two channels that will provide almost full coverage of their respective wavelength ranges in one shot. The near infrared channel will cover the Y, J and H bands, have a spectral resolution R $\sim$ 85 000 and be calibrated with ThAr lamps. We expect to reach a signal-to-noise ratio of 100 in 10 min of exposure time on a target with $J = 8$ mag. The visible channel, covering the spectral range from about 5 000 to 9 000 Å, will provide simultaneous monitoring of activity indicators (e.g. Hα, Ca II). In addition, there is a proposal for a secondary visible channel with lower resolution, restricted wavelength range and multiplex factor of about 12. We expect the instrument to start operations in 2013.

A Doppler Survey for Planetary Companions to Ultracool Dwarfs

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Low mass stars account for more than half of all of the stars in the solar neighborhood, yet we know relatively little about the frequency with which such stars have planetary companions. As a result of their small sizes and low effective temperatures, very few low-mass stars are bright enough at optical wavelengths to be targeted by planet searches. This is particularly true for Ultracool Dwarfs (UCDs), low-mass stars and brown dwarfs with spectral types later than M5. UCDs are attractive targets for planet searches since, in principle, the small mass and radius of the host enable the detection of Earth-like planets that could not otherwise be detected orbiting sun-like stars with currently available ground-based technology. I report on the development of a new technique for making Doppler measurements at near infrared (NIR) wavelengths and present results from a Doppler survey designed to be sensitive to giant planetary companions to UCDs. This survey is the largest high-resolution, NIR spectroscopic survey of UCDs that has yet been conducted, and thus these data allow an exploration of the statistical properties of the UCD population, including their binarity, rotation velocities, and space motions.

Exoplanets search and characterization with the SOPHIE spectrograph at OHP

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Several programs of exoplanets search and characterization in the Northern hemisphere have been started with the new spectrograph SOPHIE at the 1.93-m telescope of Haute-Provence Observatory, France. SOPHIE is an environmentally stabilized echelle spectrograph dedicated to high-precision radial velocity measurements. The objectives of these programs include systematic searches for exoplanets around different types of stars, characterizations of planet-host stars, studies of transiting planets through Rossiter effect, follow-up observations of photometric surveys. Latest SOPHIE results will be presented.

Exo-planets in M67

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We present preliminary results of our search for exo-planets in the old open cluster M67. M67 is a relatively rich cluster in a wide mass range, well studied for duplicity, and its chemical composition and age are very similar to that of the Sun. Our final aims are to discover exo-planets in stars similar to the Sun and more massive stars, and to shed light on the role of stellar mass in the formation of planetary systems. To this purpose, we acquired HARPS@ESO and SOPHIE@OHP accurate radial velocities for a sample of about 100 solar-type and turnoff/giant stars. We also will discuss how the new generation of instruments and Extremely Large Telescopes will be very helpful for the search of exo-planets in stellar clusters.

Characterizing Transiting Extrasolar Planets with GTC/OSIRIS

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We present recent narrow-band photometric observations of transits of known extrasolar planets, which include TrES-2b. The targets were observed using the 10.4-meter Gran Telescopio Canarias (GranTeCan, or GTC) and the tunable filter on the OSIRIS instrument. The capabilities of the tunable filter allowed us to observe the targets in two different near-infrared bandpasses with full-width at half-maxima (FWHMs) of 2.0 nm. The use of such narrow bandpasses helped to reduce the atmospheric effects that often limit the precision of ground-based transit observations, while the specific wavelengths of these bandpasses were chosen to avoid water vapor absorption and skyglow. Our results demonstrate the benefits of observing relatively bright targets ($I \sim 11$) with a tunable filter on a 10-meter class telescope. We also discuss how this technique will aid in the characterization of super-Earth-size transiting planets to be discovered by the CoRoT and Kepler missions.

Hunting for extrasolar planets around G–K giants

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G-K giants host planetary companions indicated by radial velocity (RV) variations in time series of stellar spectra. In the North for a sample of 62 very bright K giants spectra in the visual range were obtained with the high resolution coudé échelle spectrograph mounted on the 2m telescope of the Thüringer Landessternwarte Tautenburg (*TLS*). In the southern hemisphere around 300 G and K giants were monitored with *HARPS* mounted on the 3.6m telescope on La Silla. The Tautenburg survey contains at least 6 stars (around 10 %) which show low-amplitude, long-period RV variations most likely due to planetary companions. The first preliminary results of the HARPS study confirm this planet frequency. Moreover the TLS survey seems to indicate, that giant planets do not favour metal-rich stars. The last result is in contrast to what is observed among main sequence (MS) stars.

Results from the first campaign of ASTEP South and perspective for planet-findings from Dome C, Antarctica

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Dome C offers favorable conditions for planet searches thanks to a long continuous night and very good weather conditions. ASTEP South is the first phase of the ASTEP project that aims to determine the quality of Dome C for future photometric searches for transiting exoplanets and to discover extrasolar planets. The instrument consists of a front-illuminated 4k x 4k CCD camera, a 10 cm refractor, and a simple mount in a thermalized enclosure. A double-glass window is used to reduce temperature variations and its accompanying turbulence on the optical path. The telescope is fixed and observes a $4^\circ \times 4^\circ$ field of view centered on the celestial South pole. With this design, A STEP South is very stable and observes with low and constant airmass, both being important issues for photometric precision. During the 2008 Antarctic winter, between June and October, ASTEP South collected 1500 hours of data. A global analysis of the data allows us to infer the weather conditions, seeing and photometric quality of Dome C for a great fraction of the winter. Using these results in a probabilistic analysis of detection of transiting planets, we show the potential of Dome C for future planet discoveries.

Pushing planet detection to the K-band

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Extra solar planet detections have been so far constrained to the optical spectral range. Nonetheless, recent research has provided us with an astounding leap towards precise stellar RV measurements in the Near-IR range of the stellar spectra. The numerous atmospheric features in the near-IR domain have been used to our advantage to provide for a on-spectra wavelength reference. On top of the typical stellar template mask, an atmospheric mask was calculated to determine precisely the RV of the atmosphere for each spectra. This result has enabled us to reach the 10 m/s RV precision in young stellar objects, such as the less embedded T-Tauri stars. Here we extend the use of the 2D cross-correlation techniques developed for the H-band into the K-band region in order to investigate its potential to probe the existence of low-mass (stellar and sub-stellar) companions around Class I objects observed with the CRIRES spectrograph at Paranal observatory. The obtained precision so far of a few hundred m/s is not enough to detect companions of planetary mass. In this poster we discuss the limiting factors in obtaining a higher precision and the perspectives of improvement.

Transit timing analysis of the exoplanet TrES-3b

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We present nine transits of TrES-3, taken as part of a transit timing program using the RISE instrument on the Liverpool Telescope. A Markov-Chain Monte-Carlo analysis was used to determine the planet-star radius ratio and inclination of the system which are consistent with previous results. We also calculated the central transit times and uncertainties and although they are in agreement with a linear ephemeris, giving $\chi^2 = 35.07$ for 15 degrees of freedom, we interpret this to be the result of systematics in the light curves rather than a real transit timing variation. This is because the light curves that show the largest deviation from a constant period either have relatively little out-of-transit coverage, or have clear systematics. The transit times were then used to place upper mass limits as a function of the period ratio of a potential perturbing planet, showing that our data are sufficiently sensitive to have probed for sub-Earth mass planets in both interior and exterior 2:1 resonances, assuming the additional planet is in an initially circular orbit.
This poster is based on the paper Neale et al, 2009, ApJ,700,1078

MEarth's First Year of Looking for Transiting, Rocky, Habitable Exoplanets

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The ground-based MEarth survey is monitoring the brightness of 2,000 nearby, late M-dwarf stars with the goal of detecting a 2 R_{Earth} transiting exoplanet in the habitable zone of its host star. Due to the small radii of M-dwarfs, exoplanets that transit them have large planet-to-star contrast ratios, and due to M-dwarfs' low luminosities, their habitable zones correspond to two week orbits. Transit spectroscopy techniques could be used to probe the atmospheres of the exoplanets MEarth will find, potentially providing the first opportunity for such measurements of habitable worlds. This poster provides updates on MEarth's status one year after the start of the full MEarth survey and shows the results of extensive simulations of the survey's sensitivity to transiting exoplanets so far. These simulations reveal the deleterious effects of stellar variability and correlated noise on transit detection, yet give encouraging results for short orbital periods. Informed by the first year of observations, MEarth is now ready to detect and automatically trigger high-cadence follow-up of transits in progress; this practice will extend MEarth's sensitivity to longer orbits and make the detection of transiting, habitable zone exoplanets feasible.

The generalised Lomb-Scargle periodogram (GLS) and the Keplerian periodogram

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The Lomb-Scargle periodogram is a common tool in the frequency analysis of unequally spaced data that is equivalent to least-squares fitting of sine waves. We have derived an analytic solution for the generalisation (GLS) to a full sine wave fit that includes an offset and weights (χ^2 fitting). Compared to the Lomb-Scargle periodogram, the GLS requires only a few modifications and the computational effort is similar. The GLS is superior (more accurate frequencies, less susceptible to aliasing, a much better determination of the spectral intensity) and brings together several related methods (date-compensated discrete Fourier transform, floating-mean periodogram, SigSpec).

We have also implemented the GLS in an algorithm for the evaluation of the Keplerian periodogram that searches for the period of the best-fitting Keplerian orbit to radial velocity (RV) data. The systematic and non-random algorithm is capable of detecting eccentric orbits and can be a useful tool in searches for the orbital periods of exoplanets.

Fronteira Astronomical Observatory: first observations of transiting extrasolar planets

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In this poster we present the first results of photometric transit observations done at the "Observatório de Fronteira", in southern Portugal. The first observational results of measured photometric transits will be presented during this workshop, obtained with the 0.35-m telescope. The results on HD189733 and HAT-P-8 show already the technical capability of this observatory in transit photometric follow up.

High precision exoplanet transit photometry with multifiber spectrographs

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To obtain light curves of transiting exoplanets with a sub-millimagnitude photometric accuracy is still a challenging target with the present ground-based techniques, chiefly because of the tricky systematic errors which are shown to arise (Tamuz et al. 2005, Pont et al. 2006). By now, the most common method is the differential aperture photometry performed over defocused stellar images, in order to collect a big number of photoelectrons without saturating the detector, and minimizing the effects of poor flat-fielding and tracking drifts. While many good works have been carried out in this way, it has been shown that the defocus is difficult to perform on new generation AO telescopes, such as VLT, as it can give rise to unpredictable mechanical flexures (Gillon et al. 2009). Moreover, in crowded fields it is not feasible to defocus the stellar profiles up to the optimal radius without contaminating the target flux with other sources.

In order to achieve an extremely high accuracy, we propose to observe the target, along with a suitable number of reference stars, with a spectrograph mounted on a 8-10m class telescope, and to develop brand new reduction tools. A fiber-fed spectrograph with multiple microlenses arrays (called Integral Field Units, IFUs), such as GIRAFFE@VLT, allow us to disperse simultaneously the light of the stars by placing an IFU over each object. The spectra from the single fibers are then imaged on stable positions over a single CCD, and we can perform differential phometry by summing the fluxes along the dispersion direction.

This method would have many advantages: 1) we can collect an huge number of photons (therefore lowering the shot noise below one part over 10^4) without defocusing the images 2) all the systematic trends depending upon the position on the CCD are minimized 3) it is possibile to perform transit spectroscopy and photometry at the same time, and to constrain empirically systematics which depend upon the wavelength. A careful modeling of the jitter of the star centroids over the IFU focal plane will be required. We will implement every calibration and extraction task in a fully empirical way, i.e. without support of analytical models, developing specific software tools from scratch.

Our techniques are going to be tested on a two-nights GIRAFFE data set (382.C-0257A, PI: Pasquini), which covered two full transits of WASP-4b. Some calibration and instrumental problems were already reported and, for the most part, corrected.

Exploring the history of WASP-3b

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The migration history of an exoplanet may be probed by measuring the Rossiter-McLaughlin effect; an additional Doppler shift observed during transit caused by the blocking of the rotating surface of the star by a crossing planet. The planet's trajectory relative to the rotation axis of the star can be inferred from the shape of this radial velocity shift. We present the Rossiter-McLaughlin effect of WASP-3b measured using the SOPHIE spectrograph at OHP. We show that the system is well aligned, suggesting the planet underwent a relatively non-violent migration process such as proto-planetary disc interactions.

Early Highlights from the NASA Kepler Misison

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We present a cursory look at the first 33 days of science data from the mission beginning with a summary of the characteristics of the $\sim 150,000$ stars Kepler is observing. The 30-minute photometric precision measurements yield values at the expected random photon+instrument noise floor. The amplitude and frequency characteristics of the light curves were used to devise a luminosity class discriminator that is applied to stars that were not previously classified in the Kepler Input Catalog. Application of the discriminator to control samples of dwarf and giant stars suggests that the stellar classifications in the Kepler Input Catalog are reliable $> 90\%$ of the time for stars brigher than 12th magnitude. Sample light curves of variable stars are presented as well as the light curves of the 20 brightest G, K, and M dwarfs being observed by the spacecraft. A small set of solar analogs are identified and their light curves are plotted against the SOHO irradiance data of similar duration for both the active and quiet Sun. This cursory look at the data suggests that Kepler will see sufficient numbers of stars as photometrically quiet as the Sun.

Earths transmission spectrum from lunar eclipse observations

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Of the 342 planets so far discovered orbiting other stars, 58 transit the stellar disk, meaning that they can be detected through a periodic decrease in the flux of starlight. The light from the star passes through the atmosphere of the planet, and in a few cases the basic atmospheric composition of the planet can be estimated. As we get closer to finding analogues of Earth, an important consideration for the characterization of extrasolar planetary atmospheres is what the transmission spectrum of our planet looks like. Here we report the optical and near-infrared transmission spectrum of the Earth, obtained during a lunar eclipse. Some biologically relevant atmospheric features that are weak in the reflection spectrum (such as ozone,molecular oxygen, water, carbon dioxide and methane) are much stronger in the transmission spectrum, and indeed stronger than predicted by modeling. We also find the fingerprints of the Earth's ionosphere and of the major atmospheric constituent, molecular nitrogen (N2), which are missing in the reflection spectrum.

Polarization Signatures Due To Transiting Exoplanets

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Many different techniques are being used to discover and characterize exoplanets. One diagnostic which has been underutilized, surprisingly, in exoplanet studies is polarimetry. Most theoretical models have focused on using the technique of polarimetry to detect exoplanets by means of the light they scatter from their atmospheres. However, the polarization levels which are predicted from this effect are well below the sensitivity of modern polarimeters. In this project we will observationally test the alternative theory presented by Carciofi & Magalhães (2005) that provides a means of detecting exoplanets occulting their host stars by polarimetry. Instead of looking for the scattered light from the exoplanet, we will focus on the polarimetric signatures produced when exoplanets occult their host stars. During the occultation the exoplanet will block some of the light from the stellar disk. The symmetry of the stellar disk will thus be broken, producing a net linear polarization which is predicted to be within the detectable range of modern polarimeters. Measuring the occultation polarization gives us important information about the planet and the star. In particular, this technique allows for the determination of the stellar limb polarization, a quantity that is very difficult to measure and is essentially unknown to stars other than the Sun. Current and future space based missions such as *CoRoT*, *Kepler* and others will significantly increase the number of known exoplanets, providing addition prospective targets to investigate. Observations will be carried out with the use of the University of Wisconsin's Halfwave Polarimeter (HPOL). Several of us are involved in a collaboration to relocate HPOL to the Mt. Lemmon Observing Facility in Fall 2009, and this will provide us with guaranteed observing time to conduct this study.

Characterization of extrasolar planets with high contrast imaging

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For the time being, radial velocity measurement is the most efficient method in revealing extrasolar planets (most of the about 350 known planets were discovered in this way). On the other hand it doesn't say us anything about the planet's physics allowing only a dynamical and orbital characterization. After a more timid start, the search for extrasolar planets with the transit method has begun to collect very promising results (about 60 planets discovered up till now). COROT, Kepler, TESS (PLATO on more long term base) and ground-based surveys will provide many more candidates in a short term future . Moreover, for a selected sample of transiting exoplanets it is already possible to probe their atmospheres. Although very successful, both these methods are sensitive to planets which orbit quite close to their parent star. High contrast imaging will be the new frontier for exoplanet search and characterization. This technique will provide the opportunity to explore planets with masses down to the earth mass and/or orbiting at larger separation from their parent star, especially in the habitable zone. The possibility to couple an integral field spectrograph to a module for extreme adaptive optics and a 8m class telescope, in order to characterize the atmospheres of the observed exoplanets with low resolution spectroscopy is already on the way (SPHERE for VLT and GPI for South Gemini). The possibility for similar instrumentation on ELTs (EPICS) is under study. In this framework we present the advantages and limits of the high contrast imaging technique and the potential of EPICS for the characterization of planetary atmospheres in both Jupiter-like and Earth-like planets using higher resolution spectroscopy.

Detecting atmospheric spectral features of low mass planets with SIMPLE at the ESO-ELT

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SIMPLE will be a near-IR high-resolution spectrograph for the ESO-ELT designed to provide a resolving power of $R = 100,000$ covering the spectral range $0.8 - 2.5\,\mu m$ in a single frame. Spectroscopy with SIMPLE at the ESO-ELT will provide a formidable tool to observe planet atmospheric spectral features during transits. The strongest absorption features of planets are located in the IR and can be used as diagnostics of the physical and chemical conditions of the atmosphere.

Here we present the results of simulations to determine feasibility of using SIMPLE to detect the atmospheres of low-mass planets around dwarf stars. Our simulations show that for Earth-size planets in habitable orbits, the most extreme and challenging case considered, it could be possible to detect signatures of species important for habitability such as CO_2 and H_2O. Other species resulting from biological activity could be detectable only if the system is sufficiently close to the Sun. The atmospheres of other low mass planets (e.g. Venus-like, ocean-planets) are easier to detect because the cross-section of their atmospheres is larger than that of an Earth-sized planet. For a Jupiter-size planet the observation of just one transit could be enough to detect its atmospheric features.

Notes