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Contents

Abstracts

Simon Albrecht

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Oral presentation

Title: Obliquities of exoplanet host stars

Abstract: The angle between the rotation axis of a celestial body and its orbital angular momentum – its obliquity – holds information about the formation and evolution of itself and the system it is part of. I review the field of stellar obliquities in exoplanet systems, measurement techniques, results, and their interpretation in the context of planet formation and evolution. I will highlight new trends visible in the significantly enlarged star-planet obliquity sample, in particular new trends in obliquity as function of the stellar and planetary mass, the Roche lobe separation, scaled orbital separation and orbital eccentricity. I will discuss evidence for a dynamically hot and a dynamically cold population and touch on recent progress in theory and on measurements of protoplanetary disk alignment. The talk closes with an outlook on observations/simulations, which over the next few years will expand our view and will shed light on many of the possible origins of high obliquities in exoplanet systems.

This talk will be based on a PASP review (Albrecht, S., Dawson, R., & Winn, J., in prep).

Sareh Ataiee

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Oral presentation

Title: How much can ignoring disc self-gravity in hydrodynamical simulations affect the resonant configuration?

Abstract: Various studies have shown that self-gravity can alter the Lindblad torque from a disc on a planet. Although it is usually assumed that this effect cannot be important for moderate disc masses such as MMSN, we found ignoring self-gravity in hydrodynamical simulations can produce fake resonance systems. However, this problem can be solved by applying only the axisymmetric part of the self-gravity instead of performing costly full self-gravity simulations.

Marcelo Barraza

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Poster presentation

Title: Dust traps in the protoplanetary disc MWC 758: two vortices produced by two giant planets?

Abstract: Resolved ALMA and VLA observations indicate the existence of two dust traps in the protoplanetary disc MWC 758. By means of 2D gas+dust hydrodynamical simulations post-processed with 3D dust radiative transfer calculations, we show that the spirals in scattered light, the eccentric, asymmetric ring and the crescent-shaped structure in the (sub)millimetre can all be caused by two giant planets: a 1.5-Jupiter mass planet at 35 au (inside the spirals) and a 5-Jupiter mass planet at 140 au (outside the spirals). The outer planet forms a dust-trapping vortex at the inner edge of its gap (at 85 au), and the continuum emission of this dust trap reproduces the ALMA and VLA observations well. The outer planet triggers several spiral arms which are similar to those observed in polarised scattered light. The inner planet also forms a vortex at the outer edge of its gap (at 50 au), but it decays faster than the vortex induced by the outer planet, as a result of the disc's turbulent viscosity. The vortex decay can explain the eccentric inner ring seen with ALMA as well as the low signal and larger azimuthal spread of this dust trap in VLA observations. Finding the thermal and kinematic signatures of both giant planets could verify the proposed scenario.

Bertram Bitsch

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Oral presentation

Title: Formation of systems of gas giants

Abstract: Previous simulations of planet formation including pebble accretion, planet migration and disc evolution focused mainly on the evolution of single bodies. Simulations that included multi-body dynamics did not included all three effects (pebble accretion, migration or disc evolution) at the same time. I will present here simulations that include all three effects as well as multi-body dynamics with application to giant planet systems.

As the planets grow by accreting pebbles they migrate in the type-I regime mostly inwards, but as soon as they start to accrete gas efficiently they open deep gaps in the disc and enter the slower type-II migration. In this talk I will show the growth and evolution of planetary systems as function of migration speed and damping rates of eccentricity and inclination. High damping rates result in stable systems with inner super-Earths and outer gas giants, while low damping rates result in system with eccentric Jupiter planets.

Tjarda Boekholt

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Poster presentation

Title: The Origin of Chaos in the Orbit of Comet 1P/Halley

Abstract: We analyse the origin of chaos in Comet Halleys orbit in order to get a better understanding of its unusually short Lyapunov time scale. We perform N-body simulations to model Halley's orbit in the Solar System and measure the separation between neighbouring trajectories. To be able to interpret the numerical results, we use a semi-analytical map to demonstrate different growth modes, i.e. linear, oscillatory or exponential, and transitions between these modes. We find the Lyapunov time scale of Halley's orbit to be of order 300 years, which is significantly longer than previous estimates in the literature. This discrepancy could be due to the different methods used to measure the Lyapunov time scale. A surprising result is that next to Jupiter, also encounters with Venus contribute to the exponential growth in the next 3000 years. Finally, we note an interesting application of the sub-linear, oscillatory growth mode to an ensemble of bodies moving through the Solar System. Whereas in the absence of encounters with a third body the ensemble spreads out linearly in time, the accumulation of weak encounters can increase the lifetime of such systems due to the oscillatory behaviour.

Garett Brown

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Oral presentation

Title: Quantifying the Effects of Stellar Flybys on Planetary Systems

Abstract: Previous studies on the effects of stellar fly-bys on planetary systems have examined populations that result in immediate ejections, planet-planet encounters, and the general stability of multi-planetary systems after an encounter. However, subtle changes to the orbital structure of established planetary systems create small cascading effects which can build up over the lifetime of the system, without entirely destabilizing the system. We use long term n-body integrations to measure these effects by analyzing the secular frequencies using quantitative frequency analysis. Using the solar system as a model, we have measured the response and long-term variations of the fundamental secular frequencies to external perturbations. The results provide a better understanding of how stellar flybys affect long-term changes to the orbital structure and help enrich our understanding of the evolution of planetary systems.

Maxwell Cai

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Poster presentation

Title: Signatures of star clusters on Kepler planetary systems

Abstract: The Kepler mission has so far detected thousands of transiting exoplanets. Interestingly, multi-planet systems with more transiting planets tend to be dynamically cool, featured with nearly coplanar and circular orbits. In contrast, single-transiting planetary systems tend to be dynamically hot, feature one planet with high orbital eccentricity and/or spin-orbit misalignment. We study this phenomenon by simulating the dynamical evolution of multi-planet systems in star clusters. Our simulations show that the host star cluster essentially imposes a natural selection process on its planetary systems, such that the surviving planets have the orbital architecture suitable for its evolution environment. As such, the field planetary systems detected by Kepler bear signatures from its birth clusters.

Daniel Carrera

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Oral presentation

Title: Formation of short-period planets by disk migration of resonant chains

Abstract: Protoplanetary disks are thought to be truncated at the point of co-rotation with the host star, or at around 10 days. Therefore, the discovery of small planets with P ¡ 10d is a puzzle. In a recent investigation we show that these planets may form through the Type-I migration of planets locked into a chain of mutual mean motion resonances. When a resonant chain reaches the inner edge of the disk, the disk torques on the outer planets can "push" the inner planets past the inner edge of the disk. We ran N-body simulations of planet formation, starting with embryos embedded in an evolving protoplanetary disk. The simulations ran through the disk phase, and the post-disk dynamical evolution, usually involving a dynamical instability. We then modelled the Kepler detection biases including both geometric effects and a detailed model of the Kepler pipeline. Our results closely reproduce the period distribution of small Kepler planets between 1 and 100 days. In other words, the Kepler sample of short period planets is consistent with it being formed by the migration of resonant chains. This work provides valuable insight into how resonance capture, migration, and dynamical instabilities have shaped the exoplanet population.

Camille Bergez-Casalou

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Poster presentation

Title: Gas accretion onto multiple giant planets in protoplanetary discs

Abstract: The accretion of gas onto giant planets has a large impact on the structure of their surrounding disc. We study this influence to characterize the evolution of their mass. We perform isothermal hydrodynamical simulations with the Fargo2D1D code where the accretion is based on recipes from the literature (Kley 1999, Machida 2010). As we are interested into the effects of gas accretion onto the disc structure, we first investigate the influence of the initial gas surface density and viscosity of the disc for a single accreting planet. After analyzing their behavior, we investigate the case of two planets accreting gas simultaneously. These two planets are placed in different locations corresponding to resonances (4:3, 3:2, 2:1 and 3:1)

and are initially not allowed to migrate nor feel each other. The planets have 20 Earth masses initially and are assumed to be in the runaway gas accretion regime. By comparing this result with the single planet case, we are able to deduce the influence of the competitive accretion. We find that the outer planet can become larger as soon as the inner disc and the region between the planets is depleted on a viscous timescale.

Alexandre Correia

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Oral presentation

Title: Asynchronous and chaotic rotation for compact planetary systems.

Abstract: We study the spin evolution of close-in planets in compact multi-planetary systems. The rotation period of these planets is often assumed to be synchronous with the orbital period due to tidal dissipation. Here we show that planet-planet perturbations can drive the spin of these planets into non-synchronous or even chaotic states. These asynchronous configurations are possible even for nearly circular orbits and will impact the habitability of these planets. We also present a very simple method to probe the spin dynamics from the orbital perturbations.

Stefan Czesla

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Oral presentation

Title: GJ 4276: One eccentric planet or two planets in a 2:1 resonance?

Abstract: I present our analysis of the GJ 4276 planetary system. The radial velocity variations of the M4.0 star GJ 4276 were monitored with the CARMENES spectrograph for 774 days, and they clearly show periodic modulation. Our analysis of spectral activity indicators and photometric light curves excludes starspot-induced RV perturbations as the cause of the signal. The RV variation is compatible with a single, Neptune-mass planet on a highly eccentric orbit (e=0.37) with a period of 13.35 days or a system of two planets with circular orbits with a 2:1 period commensurability. Although these solutions cannot reliably be distinguished based on our RV data, both yield intriguing configurations for the GJ 4276 system.

Nazanin Davari

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Poster presentation

Title: Dynamics of Planetary Systems in Interaction with the Supermassive Black hole in the Galactic Centre

Abstract: In this poster we present our ongoing project about planetary systems around the S-star cluster in the vicinity of the supermassive black hole (SMBH) in the Galactic Centre (GC). Since S-stars might have migrated close to the SMBH from else where in the Galaxy, they may still own their planetary systems. We are going to study the fate of their planetary system after the close interaction with the central black hole in our galaxy to put constraints for future observations.

Melvyn B. Davies

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Invited Talk

Title: Survival of scattered planets in potentially habitable orbits

Abstract: The orbital properties of planets we observe may tell us something about other planets in the system. For example, planets on orbits too close to those already observed may be excluded on stability grounds. In addition, the present orbital properties may tell us about the history of a particular system. Many observed giant planets lie on eccentric orbits. Such orbits could be the result of strong scatterings with other giant planets. The same dynamical instability that produces these scatterings may also cause habitable planets in interior orbits to become ejected, destroyed, or be transported out of the habitable zone. I show how by measuring the orbital properties of any surviving gas giants, one may learn something about the likelyhood that the system contains habitable worlds.

Francesco Maria Flammini Dotti

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Poster presentation

Title: The dynamical fate of Solar systems in open clusters

Abstract: Most stars in the Galaxy form in stellar groupings that either dissolve within several tens of millions of years, or evolve into open clusters. It is important to study the dynamics of planetary systems in such structures to explain the properties of observed exoplanets. Here, we numerically evolve open star clusters with planetary systems by combining the star cluster code NBODY6++GPU code with the planetary system code REBOUND. We use different sets of initial conditions, such as the virial ratio and stellar density, and evolve the system for 50 Myr. We find that stellar encounter properties, the star cluster density, and the planetary system architecture are the main factors that affect the evolution of the planetary systems. Although most planetary systems remain intact, others lose most of their outer planets, while some are stripped of all planets. Finally, we find that the presence of the planet Jupiter plays a prominent role in the survival chances of terrestrial planets.

Stefan Dreizler

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Oral presentation

Title: Rocky planets around a low-mass star

Abstract: We will present the results from an intensive RV monitoring of a very late-type star using CARMENES. We find two potentially rocky planets, one in the conservative, one in the optimistic habitable zone of this star. The system may turn out to be dynamically interesting since the two planets are close to a 1:2 period commensurability. The star is very close to the ecliptic, Earth will be visible as transiting planet from those planet in near future.

Sergey Efimov

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Oral presentation

Title: Secular dynamics of resonant Kuiper belt objects: Kozai-Lidov cycles and adiabatic chaos (S.Efimov and V.Sidorenko)

Abstract: We study secular effects in dynamics of minor bodies in mean-motion resonance (MMR) within restricted three-body problem. Using a system "star-planet-asteroid" MMR p:(p+q) can be defined as orbital configuration in which asteroid completes p rotations around the star in the same amount of time the planet completes p+q rotations (p and q are integer numbers). Special attention is paid to exterior first-order MMRs (q=1). In Kuiper belt these resonances are represented by large populations of objects such as plutino and twotino, which are the objects in 2:3 (p=2) and 1:2 (p=1) MMRs with Neptune respectively.

One of the key features, that distinguish our model from already existing ones, is the applicability to orbits with arbitrary values of eccentricity and inclination. It was made possible by combination of the approach developed by Wisdom (1985) with semi-analytical methods based on numerical averaging of disturbing function. The results reveal the possible scenarios of secular evolution, including a variety of Kozai-Lidov cycles, some of which appears to be new and unique.

The model also allows studying the chaos in the system, with a focus on stochastisation mechanism, which is known as adiabatic chaos (Neishtadt, 1987). While the existence of chaos in first-order MMRs was indicated by numerical simulations (Sussman and Wisdom, 1988), it has not received a proper attention in the past from theoretical point of view.

Many specific cases of Kozai-Lidov cycles, as well as mixing in stochastic layer and some other dynamical effects predicted by our model, are illustrated by examples from dynamics of known Kuiper belt objects.

Ekrem Murat ESMER

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Poster presentation

Title: Stability of NY Virginis System in the Light of New Eclipse Timing Data

Abstract: NY Virginis is an Algol type eclipsing binary which consists of a subdwarf B primary and an M type main-sequence secondary with a very short orbital period of 2.4 h. Initially, Qian et al. (2012) and later Lee et al. (2014) suggested the presence of circumbinary planets around the binary by analyzing the eclipse timing variations. Recently, Pullet et al. (2018) and Batuerk & Esmer (2018) pointed out that the new mid-eclipse timings deviate significantly from the models of Qian et al. (2012) and Lee et al. (2014). By using the recently published and our own data sets acquired with the 1 m telescope T100, in TUBITAK National Observatory of Turkey, we analyzed the eclipse timings with different models in the frame of Markov Chain Monte Carlo (MCMC) method and determined the best fitting model according to their likelihood ratios. We performed a stability test by using MERCURY6 package (Chambers, 1999) within the $\pm 3\sigma$ range of the model parameters to discuss the existence of the circumbinary planets.

Sebastian Marino Estay

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Oral presentation

Title: Inward scattering of exocomets by planet chains

Abstract: Exocomets scattered by planets have been invoked to explain observations in multiple contexts. I investigated how the process of comet scattering is affected by the architecture of a planetary system, to determine whether they can lead to observable levels of dust in the inner regions (e.g. exozodis) and the amounts of volatile-rich material they can deliver to inner planets. Using N-body simulations, I modeled systems with different planet mass distributions and planet spacing. I found that tightly packed low mass planets are the most efficient at delivering material to exozodi regions (5-7% of exocomets end up within 0.5 AU at some point), although the exozodi levels do not vary by more than a factor of ≈ 7 when changing the planetary system architecture, which could explain why this phenomenon is so common. On the other hand, the density of particles between the planets can vary by two orders of magnitude and does not necessarily correlate with the exozodi level, being highest for systems of low mass planets with medium spacing and lowest for

tightly packed high mass planets. Moreover, I traced the number of impacts per inner planet, finding that exocomets could be efficient at delivering material to inner planets with impact probabilities of 0.1-1%, which varies as a function of the planet masses and spacing. The best systems at delivering are the ones with low mass outer planets and medium spacing. Finally, I will show a similar analysis applied to Trappist-1(in collaboration with Dr. Q. Kral) where we determined which of the known planets would accrete more material (including volatiles) if comets were transported in from the outer regions via different mechanisms.

Virginie Faramaz

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Invited Talk

Title: Exoplanetary Systems Dynamics with ALMA

Abstract: One fruitful way to investigate exoplanetary systems dynamics is to examine the gravitational imprints exoplanets leave on debris disks as they interact with them, and which appear under the shape of large-scale asymmetries (gaps, warps, spirals, eccentric rings)The variety of these gravitational imprints inform us in turn on the variety of existing exoplanetary systems and help us place our own Solar System in context. They give us as well access to the content in exoplanets in systems where these are too distant from their star, too old, or not massive enough to be detected by our current techniques and facilities.By combining interferometric techniques and observations at (sub)millimeter wavelengths, the ALMA observatory has made it possible to observe these prints with an unprecedented clarity. In this talk, I will expand on why ALMA has been revolutionary for the field of exoplanetary systems dynamics, and will review some of its most important results.

Jantje Freudenthal

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Oral presentation

Title: Kepler-82f - a new non-transiting planet from photodynamical modelling

Abstract: Combining 9 years of space-based observations and ground-based follow-ups, we carried out a photodynamical analysis revealing a new non-transiting planet in the Kepler-82 system. In this system the outer planets, b and c, show transit timing variations (TTVs) which are not fully explained by their interaction. The TTVs of Kepler-82c contain a second signal which can only be explained by a further outer planet. Our comprehen- sive analysis combines the numerical integration of the systems dynamics over the time span of observations with the transit light curve model to provide a coherent description of all observations simultaneously. We developed it as part of the KOINet, a multi-site network of telescopes around the globe organized to follow-up KOIs with large TTVs, to en- sure an adequate modelling of our objects. Our model is coupled with a Markov chain Monte Carlo algorithm, that helps explore the parameter space. Applied to the Kepler-82 long cadence data, short cadence data and 3 new transit observations from the years 2014-2018 obtained by the KOINet, our modelling reveals a new planet, Kepler-82f, being near the 3:2 resonance to Kepler-82c.

Pavol Gajdos

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Poster presentation

Title: Resonances in the Kepler-18 system

Abstract: We present a new study of resonances between the exoplanets in the Kepler-18 system. This system consists of three planets - one super-earth and two Neptune-mass planets. The orbital period of these planets are close to the mean-motion resonance 1:2:4. Resonance 1:2 between two bigger planets is clearly visible in transit-timing variations. Firstly, we studied if also the smallest planet is in mean-motion resonance. There is no evidence of any resonance from the transit-timing analysis. Using different numerical simulations, we followed changes of orbital parameters of all planets caused by the resonances on a long-time scale. The evolution of the resonance between two Neptune-mass planets was observed using a critical angle. From the constructed map of stability, we also found out that there are stable regions between the orbits of known planets in this system.

Nikolaos Georgakarakos

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Oral presentation

Title: Dynamical stability analysis for the six planet system HD34445: an attempt to validate the radial velocity solution.

Abstract: In 2017, the star HD34445 which was already known to host a planet, was announced to have another five planets. It is a rather dense planetary system with some of its planets having separations of fractions of an au. In this work we investigate the dynamical stability of the six planet system in order to check the validity of the orbital solution acquired. We achieve that by a series of numerical experiments, where the dynamical stability of the system is tested on different timescales. By varying the orbital elements and masses of the system within the error ranges provided, we find that for a large area of the parameter space we can produce stable configurations and therefore conclude it is very likely that the HD 34445 planetary system is real. Some discussion about the potential habitability of the system is also done.

Evgeni Grishin

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Oral presentation

Title: Formation of Hot Jupiters and Ultima-Thule-like objects from non-secular Lidov-Kozai oscillations

Abstract: In hierarchical triple systems, The Lidov-Kozai mechanism excites large eccentricity and inclination oscillations of the inner binary. The maximal eccentricity is simply derived and widely used. However, for mildly hierarchical systems, non-secular perturbations affect the evolution. We account for fast non-secular variations and find a new analytic formula for the maximal eccentricity. We find that the maximal eccentricity is generally enhanced, and sometimes even unbound, allowing closer encounters between the inner binary components, thus significantly changing their interaction and its final outcome. We demonstrate our results to calculate the formation and disruption rates of hot Jupiters (HJs). We find that more HJs migrate from further out, but they are also tidally disrupted more frequently, while the overall formation rate remains unchanged. Nevertheless, the different rates could manifest in different underlying distribution of observed warm Jupiters. In addition,

we propose that non-secular Lidov-Kozai evolution is responsible for the formation of the recently discovered contact binary (486958) 2014 MU69 (Ultima-thule) inner Kuiper belt. Contrary to the secular case, the inclination during the collision is chaotic, and therefore more plausible to yield the observed inclination of 92 deg.

Sam Hadden

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Oral presentation

Title: Resonance overlap criterion and the onset of chaos for eccentric planets

Abstract: I describe an analytic criterion to predict the onset of chaos in systems consisting of two closely-spaced, massive, and eccentric planets. Given a planet pair's spacing and masses, the criterion predicts the eccentricities at which the onset of large-scale chaos occurs. The onset of chaos is predicted based on overlap of mean motion resonances as in Wisdom (1980)'s pioneering work. Whereas Wisdom's work was limited to the overlap of first-order resonance and therefore to nearly circular planets, we account for resonances of all orders, allowing us to consider resonance overlap for planets with arbitrary eccentricities up to orbit-crossing.

Nader Haghighipour

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Oral presentation

Title: Do Circumbinary Planets Stop Migration at the Boundary of Stability?

Abstract: It is widely accepted that circumbinary planets form at large distances from their host binaries and undergo (substantial) radial migration. It is also well understood that in a circumbinary disk, planets stop migration at the edge of the disk cavity due to the tidal effect of the binary on the gaseous disk. It has been argued that the latter also corresponds to the boundary of orbital stability, promoting the idea that circumbinary planets stop migration at the edge of the stability region. To examine this idea, we have initiated a large program on understanding planet migration in circumbinary disk, focusing specifically on the stopping locations of planet in term of the disk's physical properties. We considered the central binary to be Kepler 38 and planet to be 10 and 15 Earth-masses, and carried out a large

number of planet migration simulations for different values of the viscosity and scale height of the disk. In order for simulations to be self-consistent, we allowed the planet interact with the disk and migrate as the disk evolves. As expected, in the majority of cases, planet migrated inward and stopped at the same location on the edge of the cavity. This is consistent with the fact that planet migration is independent of the dynamical history of the system and is solely driven by the physical properties of the gas. Our simulations did not indicate any logical and causal connection between the stopping location of the planet and the boundary of orbital stability around the binary. We will present the results of our simulations and discuss their implications in more detail.

Paul Heeren

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Oral presentation

Title: Is there a planetary companion in the eccentric binary system Epsilon Cygni?

Abstract: From a long-term RV survey of G and K giant stars at Lick Observatory and the SONG telescope we have identified, among others, a number of stellar binary systems that might harbor additional planetary companions. Here we report about the highly eccentric (e 0.93) binary system Epsilon Cygni, whose RV curve shows short-periodic variations that closely resemble the signal of a Jupiter mass planet orbiting the evolved primary component. However, the Keplerian elements of the putative planet's orbit change strongly over time, and in extensive dynamical simulations of the system no stable solutions could be found. We therefore investigate the possibility that the system might actually be a hierarchical triple, with the primary component being orbited not by a single stellar companion, but by a close binary. We test the stability regions of such systems and whether the changing gravitional field of the accompanying binary can induce the observed short-periodic RV variations on the primary component.

David M. Hernandez

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Oral presentation

Title: Should N-body integrators be (fully) symplectic?

Abstract: Central to dynamics computations in planetary astrophysics is the solution of the N-body problem. Over long-term time scales, symplectic integrators have seen important successes, starting with development of the Wisdom-Holman integrator. However, there are contradictions in the literature as to what a symplectic integrator is and whether it's useful. The aims of this talk are to (i) propose a new definition of a symplectic integrator, and show that several codes do not satisfy it, (ii) show that symplectic integrators must be symplectic everywhere in phase space for periodic orbits to exist, and (iii) show that exploiting the time-symmetry and differentiability of the N-body problem gives significant improvement to dynamical solutions.

References: arXiv:1903.04972, arXiv:1904.03364, arXiv:1902.03684.

Yair Judkovsky

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Oral presentation

Title: Probing Exoplanetary Orbital Precession from Transit Variations

Abstract: Non-Keplerian dynamics of planetary orbits may manifest in the stellar light-curve as variations of different types (including, but not limited to, TTVs). This study aims to detect secular variations in the orbit by observing and interpreting Kepler photometric data.

By assuming that the orbital motion is dominated by nodal and apsidal precession, we provide analytical approximations for the light-curve transit parameters as a function of the orbital variations. We search the Kepler data for such variations and report candidate systems.

Detecting such a dynamical scenario provides information regarding the possible existence of non-transiting planetary companions, or the non-spherical mass distribution of the host star. The variations may imply forces out of the orbital plane, and thus probe mutual inclinations among components of the system.

Miriam Keppler

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Oral presentation

Title: Witness planet-disk interactions at the stage of formation

Abstract: PDS 70 hosts the most robustly imaged young, forming planet to date. Using multi-epoch observations with SPHERE, PDS 70 b has been detected at a distance of about 22 au from the star. With the mass of a few Jupiter masses, it has carved out a large gap within its host protoplanetary disk. I will present new ALMA observations of the disk around PDS 70 showing evidence of rich substructures in both, dust and gas. While the CO integrated intensity shows a gap at the location of PDS 70 b, the gas kinematics as well as the dust continuum imply a depletion of material well beyond the location of the planet, which may require the presence of an additional low-mass companion to account for the observed disk morphology. PDS 70 therefore represent a unique system to study planet-disk interactions at a very early stage.

Veselin Kostov

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Oral presentation

Title: L 98-59: Three Transiting, Terrestrial-Sized Planets Orbiting a Nearby M-dwarf observed by TESS

Abstract: We present the TESS discovery of three terrestrial-sized planets transiting L 98-59 (TOI-175, TIC 307210830) – a bright M dwarf at a distance of 10.6 pc. Using the Gaia-measured distance and broad-band photometry we find that the host star is an M3 dwarf. Combined with the TESS transits, the corresponding stellar parameters yield planet radii ranging from 0.7REarth to 1.3REarth. All three planets have orbital periods between 2.25 and 7.45 days, with the outer pair just wide of a 2:1 period resonance. Diagnostic tests produced rule out common false positive sources which, along with dedicated follow-up and the multiplicity of the system, lend confidence that the observed signals are caused by planets transiting L 98-59. The L 98-59 system is interesting for a number of reasons: the host star is bright (K = 7.1 mag) and the planets are prime targets for future follow-up observations including precision radial-velocity mass measurements and transit spectroscopy with the JWST; the near resonant configuration makes the system a laboratory to study planetary system dynamical evolution; and three planets of similar size in the same

system present an opportunity to study terrestrial planets where other variables (age, metallicity, etc.) can be held constant. L 98-59 will be observed in five more TESS sectors, which will provide a wealth of information on the three currently known planets and have the potential to reveal additional planets in the system.

Martin Kuerster

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Oral presentation

Title: Hunt for Additional Planetary Companions: Revisiting Single Planet Systems with High Precision Doppler Spectroscopy

Abstract: I will present results from a Doppler survey carried out with HARPS, FEROS and CARMENES for a sample of 45 stars, which were previously reported to have a single planetary companion in orbit. Most of these planetary discoveries were announced based on sparse radial velocity (RV) data samples, insufficient precision and sometimes incomplete phase coverage. Our survey aims to increase the observational efforts for these targets in an attempt to detect additional planets. So far, almost half of our targets are already showing strong indications of additional companions. For these systems with additional companions, we have conducted detailed statistical and dynamical analyses of the RV data and studied the long-term stability. We have a strong reason to believe that a significant fraction of the single RV planets are in fact either pairs of low-eccentricity near-resonant planets misinterpreted as a single planet or systems with a long-period massive companion, which can be revealed only by increasing the temporal baseline of the observations. Since multiple planet systems are important for probing planetary formation and evolution scenarios, I will emphasize the importance of further follow-up of RV planet hosts.

Jacques Laskar

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Invited Talk

Title: AMD-stability of planetary systems

Abstract: Due to the increasing large number of discovered planetary systems, it becomes important to set up some framework for a rapid understanding of the dynamics of the discovered systems, without the need of computer intensive numerical simulations. This has been the goal of our recent work on AMD-stability.

In a planetary system, the AMD (Angular Momentum Deficit) is the difference between the planar circular angular momentum and the total angular momentum. This quantity is conserved between collisions in the average system, and decreases during collisions.

This leads to the concept of AMD-stability. A planetary system is AMD-stable if the AMD in the system is not sufficient to allow collisions. The advantage of this notion is that it becomes possible to verify very quickly whether a newly discovered planetary system is stable or potentially unstable, without any numerical integration of the equations of motion.

Chi Ho Lau

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Oral presentation

Title: Mutual Inclinations in Multi-Planet Systems with External Perturbers (Chi Ho Lau, Man Hoi Lee, and D. N. C. Lin)

Abstract: Some multi-planet systems are known to have distant giant planet or stellar companions. The excitation of mutual inclinations in a multi-planet system by a distant inclined perturber has also been proposed as an explanation for the "Kepler dichotomy" of the large number of single-transit systems relative to multi-transit systems. We have performed numerical simulations to study the mutual inclination of a planet pair perturbed by a distant companion. For a planet pair interacting through secular interactions, in addition to the strong- or weak-coupling limit where the orbital angular momentum vectors of the planets precess together or independently (Lai & Pu 2017), we find regimes where a highly inclined perturber can induce larger mutual inclination and eccentricities of the planetary orbits through the Lidov-Kozai mechanism, leading to instability in some cases. This is different from the Lidov-Kozai oscillations of the planet pair found by Pu

& Lai (2018), when the mutual inclination of the planet pair is sufficiently large. We have also studied planet pairs in or near 2:1 mean-motion resonance (as in, e.g., Kepler 25 and Kepler-56) and found that a distant perturber can excite a larger mutual inclination compared to the non-resonant case if the planet pair is deep in the resonance. This work was supported in part by the Hong Kong RGC grant HKU 17305015.

Gregory Laughlin

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Invited Talk

Title: Obliquity-Driven Sculpting of Exoplanetary Systems

Abstract: Short-period compact systems are rarely found with planet pairs in mean-motion resonances, but there is a significant overabundance of planet pairs lying just wide of the first-order resonances. Previous work suggests that tides raised on the planets by the host star may be responsible for forcing systems into these configurations by draining orbital energy to heat. Such tides, however, are insufficient unless there exists a substantial and as-yet-unidentified source of extra dissipation. I will argue that this cryptic heat source may be linked to obliquity tides generated when a large axial tilt is maintained by secular resonance-driven spinorbit coupling. Strong evidence exists that typical compact, nearly coplanar systems frequently experience this mechanism, and I highlight additional features in the planetary orbital period and radius distributions that may be its signatures. Extrasolar planets that maintain large obliquities will exhibit infrared light curve features that are detectable with forthcoming space missions. The observed period ratio distribution can be explained if typical tidal quality factors for super-Earths and sub-Neptunes are similar to those of Uranus and Neptune.

Man Hoi Lee

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Oral presentation

Title: Numerical Determination of the Elements of Circumbinary Orbits

Abstract: Planets and satellites orbiting a binary system exist in the Solar System and extrasolar planetary systems. A proper description of a circumbinary orbit is in terms of the circular motion of the guiding center at the frequency of the mean motion, the free eccentricity at the epicyclic frequency, the forced eccentricity at the mean motion, and oscillations forced by the non-axisymmetric components of the binarys potential. We show that the amplitudes and frequencies of these terms can be extracted from numerical orbit integrations by applying fast Fourier transformation to the cylindrical distance between the circumbinary object and the center of mass of the binary as a function of time. This allows a measurement of the free eccentricity (which is a free parameter in the theory), as well as accurate values for the parameters with only first-order analytic expressions. We apply this method to several Kepler circumbinary planets and the satellites of the Pluto-Charon system. For the satellite Styx of Pluto-Charon, which has the smallest orbital period ratio (3.16) of the circumbinary objects examined, the epicyclic frequency is significantly different from the analytic value, which explains some discrepancies in the orbital parameters obtained from fitting observations.

Adrien Leleu

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Oral presentation

Title: Evolution of the co-orbital resonance in protoplanetary disc

Abstract: Despite the existence of co-orbital bodies in the solar system, and the prediction of the formation of co-orbital planets by planetary system formation models, no co-orbital exoplanets (also called trojans) have been detected thus far. I will present my latest results regarding the stability of co-orbitals exoplanets under dissipation and mass change (accretion). An analytical model is developed to extract a stability criterion as function of the planetary masses and the dissipative forces. This criterion is then compared to both the evolution of co-orbital exoplanets in protoplanetary 1-D disc models, and hydrodynamics simulations. This study is a

step toward understanding which should be the preferred configuration and environment of co-orbital exoplanets.

Christoph Lhotka

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Oral presentation

Title: Temporary capture of charged dust close to outer mean-motion resonance with a planet

Abstract: We investigate the dynamics of charged dust close to outer mean-motion resonances with planet Jupiter. The importance of the interplanetary magnetic field on the orbital evolution of dust is clearly demonstrated. New dynamical phenomena are found that do not exist in the classical problem of uncharged dust. We find changes in the orientation of the orbital planes of dust particles, an increased amount of chaotic kinds of orbital motions, sudden 'jumps' in the resonant argument, and a decrease in time of temporary capture due to Lorentz force.

Anne-Sophie Libert

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Oral presentation

Title: Secular dynamics of non-coplanar extrasolar systems

Abstract: Due to the limitations of the radial velocity technique, no indication on the spatial configuration of giant planetary systems can usually be given by the observations. We aim at constraining the spatial configuration of several RV-detected two-planet extrasolar systems. Through an analytical study based on a first-order secular Hamiltonian expansion and numerical explorations performed with a chaos detector, we identify ranges of values for the orbital inclinations and the mutual inclinations which ensure the long-term stability of the system. We find that long-term regular evolutions of 3D configurations exist for all the selected systems, either at low mutual inclinations, or at high mutual inclinations preferentially if the system is in the Lidov-Kozai resonance. A rapid destabilization of highly mutually inclined orbits is commonly observed, due to the significant chaos that develops around the stability islands of the Lidov-Kozai resonance. Particular attention is also given to planetary systems whose inner planet evolves closer to the star, and we show how the relativistic effects influence the extent of the Lidov-Kozai resonant region.

Joint work with M. Volpi and A. Roisin

Rafael Luque

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Oral presentation

Title: A second Jupiter orbiting in 4:3 resonance in the 7 CMa system

Abstract: We present the discovery of a second planet orbiting the K-giant star 7 CMa based on 166 high-precision radial velocities obtained with Lick, HARPS, AAT and SONG facilities. The periodogram analysis reveals two periodic signals of approximately 745 and 1000 days, associated to planetary companions. The double-Keplerian orbital fit of the data suggests possible strong interaction between the planets. The system is consistent with two Jupiter-like planets with minimum masses 2 Mjup and 0.9 Mjup, orbiting at semi-major axes of 1.8 au and 2.2 au, respectively. Given the small orbital separation and the large minimum masses of the planets, a more accurate N-body dynamical modeling of the available data is adopted. The dynamical best-fit solution leads to collision of the planets, and DEMCMC techniques are performed to explore the long-term stability configuration of the system. The result from the stability analysis indicates that the two-planets are trapped in a low-eccentricity 4:3 mean-motion resonance, in an anti-aligned configuration less than 1 sigma away from the best derived fit to the data. This is only the third discovered system to be inside a 4:3 resonance, making it very valuable for planet formation and orbital evolution models.

Rosemary Mardling

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Invited Talk

Title: Relaxation of resonant two-planet systems and their TTVs

Abstract: Many two-planet systems reside near or inside first-order resonances, while many multi-planet systems form resonant chains. These are normally the product of planet-disk interactions during the time of formation, with eccentricity damping and migration resulting in a relaxed system with fewer degrees of freedom than for an arbitrary two-planet system. Are most multi-planet systems in this state? Even if they reside ‘far’ from resonance? A simple formulation describing two-planet systems will be presented which is valid inside, across and outside resonance. We will show that all such systems are governed by a single two-parameter ordinary integro-differential equation, and that all system information (variation

of eccentricities, orbital frequencies, resonance angles, apsidal orientations, transit timing variations or TTVs) can be derived from its solution. An expression for the TTVs can be easily inverted to solve for the planet masses (and other system parameters) when both planets transit; if no valid inversion is possible (given sufficient signal to noise for the TTVs), it is possible to infer the existence of additional non-transiting planets, the signature of which will be imprinted on the signal.

Jakub Morawski

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Oral presentation

Title: υ Andromedea revisited. Dynamical characterization and a fourth outer Jovian planet in the system.

Abstract: The Upsilon Andromedae system was the first multiplanetary exoplanet system discovered around a main sequence star, with three planets confirmed in 1999. As a three planet system it has been studied extensively, with numerous dynamical fits and stable solutions for mutual inclinations proposed. However, in Curiel et al. 2011, it was shown that there is a fourth planet in the system, which due to a very long orbital period of almost 12 years, could not have been discovered before. By including new data taken with the HARPS spectroscope in November 2018, we update the orbital parameters of the outer planet's orbit, which so far hadn't been well constrained. We also present results from dynamical coplanar fit with variable inclination, which raise evidence that the system might be much closer to edge-on then hitherto assumed (based on fits treating Ups And as a 3 planet system).

Anna Penzlin

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Oral presentation

Title: Dynamics of circumbinary discs and planet migration

Abstract: As of today, there are about 10 planets detected through the Kepler space mission in a p-type orbit around a stellar binary. In all cases the planets reside close to the instability limit. To understand the process that lead to planets in these orbits we need to understand the formation environment, the circumbinary disc.

Due to angular momentum transfer from the binary a large gap forms in the circumbinary disc, that becomes eccentric and precesses slowly prograde around the binary. The density profile and structure of this disc is crucial to understand the final position of a migrating, embedded planet.

Using 2D locally isothermal hydrodynamic simulations we vary parameter settings such as binary eccentricity, and aspect ratio and viscosity of the disc and investigate the following questions: How do these parameter influence gap size and eccentricity and precession period? What are the underlying primary excitation processes in parameter space?

Finally, by comparing these initial setting we identify parameters of a disc that allow a planet to move close to the observed orbits in the Kepler systems.

Antoine Petit

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Poster presentation

Title: High order regularised symplectic integrator for collisional planetary systems

Abstract: We present a new mixed variable symplectic (MVS) integrator for planetary systems, that fully resolve close encounters. The method is based on a time regularisation that allows keeping the stability properties of the symplectic integrators, while also reducing the effective step size whenever two planets encounter. We use a high order Wisdom-Holman scheme such that it is possible to integrate with large time steps far away from close encounters. We show that this algorithm is able to resolve almost exact collisions (i.e with a mutual separation of a fraction of the physical radius) while using the same time-step as in weakly perturbed problem such as the Solar System. We demonstrate the long term behaviour on systems of

six super-Earths experiencing strong scattering for 10 kyr. We compare our algorithm to hybrid methods such as MERCURY and show that we obtain better energy conservation for an equivalent computational cost.

In collaboration with : J. Laskar, G. Boue, M. Gastineau. Article in preparation.

Gabriele Pichierri

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Oral presentation

Title: The onset of instability in resonant chains

Abstract: Planets smaller than Saturn, typically Super-Earths and Mini-Neptunes, undergo so-called type-I migration in the proto-planetary disc in which they form. When multiple planets are orbiting the same star, the inner one stops migrating at the inner edge of the disc and a favoured outcome of the slow, convergent orbital transport of the planets is the formation of a chain of mean motion resonances. When the disc is dissipated away and the damping forces applied by the disc are removed, the resulting system may be dynamically stable or unstable. Observations show that only a small fraction of these resonant chains should be stable, and these instabilities are indeed found in N-body simulations. In particular, previous numerical simulations showed that the maximum planetary mass for a resonant to remain stable decreases with increasing number of planets and increasing compactness of the system, but the origin of the instability was not understood. We focus on the case of three equal-mass planets in the 3:2 - 3:2 mean motion resonant chain and we study which dynamical phenomena lead to a loss of stability if the planetary mass is larger than some threshold. We identify a set of secondary resonances between the libration frequencies in the mean motion resonance and a sub-frequency of the synodic period 2 pi (1/P1-1/P2). These secondary resonances excite the amplitudes of libration of the mean motion resonances. We generalise this mechanism to different chains of mean motion resonances involving a larger number N of planets and/or a higher index k of the k:k-1 mean motion resonances, obtaining an analytical scaling for the maximal planetary mass that guarantees stability, as a function of N and k. The results are in qualitative agreement with the numerical experiments mentioned above, thus giving a theoretical understanding of the instabilities observed in the simulations, as well as a better grasp on the fingerprint of the planetary dynamical history that is contained in the current exoplanets sample.

Alice Quillen

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Invited Talk

Title: Spin dynamics in multiple planet and multiple satellite systems

Abstract: Exoplanet spin state strongly influences predicted exoplanet climate and habitability and may be detectable. Close encounters, drifting secular and mean motion resonances between satellites or exoplanets can tilt their obliquities. Tumbling caused by spin resonance can enhance tidal heating and the eccentricity damping rate. Because they influence spin resonant frequencies, massive exoplanet satellite systems might be inferred from measurements of exoplanet spin states.

Andreas Quirrenbach

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Invited Talk

Title: Giant Stars: From Radial Velocities to Planetary Systems

Abstract: It is quite common to find periodic signals in time series of precise radial velocities that cannot unambiguously be attributed either to a planetary companion or to intrinsic variability of the star. K giants are particularly difficult in this respect, as they display relatively large intrinsic RV variations, which are only partially understood, and depend strongly on the specific parameters (temperature, gravity, evolutionary state) of each individual star. Because of relatively strong p-mode oscillations, radial-velocity surveys of giant stars are sensitive only to gas giant planets. Nevertheless, they are important for probing the population of these objects orbiting intermediate-mass stars. Several systems have been found that are particularly interesting from the dynamical point of view; these include the resonant system Oph (a giant star orbited by two brown dwarfs) and planets in stellar binaries, apparently at the edge of stability. I will present a few examples, and discuss statistical implications.

Sabine Reffert

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Poster presentation

Title: Statistics of Multi-Planetary Systems and Planets in Stellar Binaries involving Giant Stars

Abstract: Our Lick radial velocity survey (1999-2011) for planets around G and K giant stars has produced a relatively large number of systems composed of either several planets or planets in stellar binaries. Many of the outer orbits have periods of several decades or longer. Since 2015 we follow up 17 of such systems with SONG, in an effort to pin down these long periods and to establish the orbital configurations of those systems. Here we provide a statistical overview of the results obtained so far.

Katja Reichert

(Astronomisches Rechen-Institut - Zentrum fr Astronomie der Universitt Heidelberg)

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Poster presentation

Title: How planetary systems are shaped by their birthplace

Abstract: Young stars are almost exclusively found in groups, suggesting that most stars - and hence also most planets - form in stellar associations or clusters. Our Solar System is also thought to have formed in a clustered environment since isotopic ratios in meteorites indicate the occurrence of a supernova explosion close to the solar protoplanetary disk. Some star clusters dissolve within tens of millions of years but some also survive for hundreds of millions of years. In such environments, close stellar encounters are frequent, significantly affecting the dynamical architectures and stability of the planetary systems around those stars. We want to find out whether - and if so, to what extent - the currently observed diverse planetary systems still contain some key information about the conditions at the time they were formed in a stellar association or open cluster. To follow the dynamical evolution of planetary systems in star clusters we use current supercomputing hardware and N-body codes. The star clusters are simulated using NBODY6++GPU, while the LonelyPlanets Standalone (LPS) code is used to separately simulate the effect of the stellar encounters on the planetary systems. Preliminary results are shown for 200 multi-planetary systems inside a star cluster containing 16 000 stars ($\sim$8000 solar masses).

Laetitia Rodet

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Oral presentation

Title: Fly-bys of HD 106906: dynamics of a planet in a complex evolving architecture

Abstract: Planetary systems exhibit diverse and sometimes extreme architectures, and the young (13 Myr) system HD 106906 is a rare example of this diversity. Located in the Lower Centaurus Crux group, it comprises a tight binary, an asymmetric debris disk and a giant planet at very wide separation (¿ 700 au). Given its present configuration and the multiple observations gathered so far, the HD 106906 system represents a unique test-bed for the formation and dynamical evolution models of planetary systems. In a previous study (Rodet et al. 2017), we suggested a formation scenario that accounts for the peculiarities of the system architecture, involving interactions with the binary, mean-motion resonances and a stellar fly-by. Recently, two fly-by candidates have been evidenced with Gaia data (De Rosa et al. 2019). I will present how we can refine the formation scenario using the perturbers known characteristics. The study was done with a new symplectic N-body code that handles evolving architectures in multiple systems, which I will also introduce in my talk.

Thomas Rometsch

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Poster presentation

Title: Forming transition disks with planets

Abstract: Transition disks are protoplanetary disks often showing large inner holes or very wide gaps in mm observations. One possible scenario for their formation is the presence of an embedded planetary systems. Following this scenario and using 2D hydrodynamic simulations, we study the evolution of a disc with two embedded planets and a focus on emerging global, annular or asymmetric structures as well as the mass accretion of gas and dust onto the star across the planetary system. Preliminary results with an outward migrating pair of planets show the creation a large inner hole and an enhancement in accretion rate compared to a standard viscous evolution, reproducing two main characteristics of transition disks. Finally, we produce synthetic images of the disk system to enable comparison to observations.

Maria Paula Ronco

(Instituto de Astrofisica - Pontificia Universidad Catolica de Chile - Nucleo Milenio de Formacion Planetaria)

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Oral presentation

Title: Formation of Solar System Analogues: from the gaseous protoplanetary disk to the final stage of giant impacts

Abstract: We present results on the formation and evolution of Solar System Analogues (SSA) and water delivery on to the rocky planets formed within their habitable zones. To find suitable initial conditions to form SSA, we first developed a planetary population synthesis analysis by improving a model of planet formation that studies the evolution of a planetary system during the gaseous phase. The results of this analysis provided us with embryo distributions, planetesimal surface density, eccentricity and inclination profiles of SSAs at the time the gas of the disk is completely disipated, to be used as initial conditions for the developed of N-body simulations to study the post-oligarchic growth of these systems. Our simulations are based on formation scenarios that present different characteristics regarding the planets type I migration rates and the size of the planetesimals. Our results suggest that the formation of potentially habitable planets (PHPs) with high water contents seems to be a common process in this kind of scenarios. However, the efficiency in forming PHPs seems to be related to the size of the planetesimals. The smaller the planetesimals, the greater the efficiency in forming PHPs.

Maria Paula Ronco

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Poster presentation

Title: Thermal torque effects on the migration of growing low-mass planets

Abstract: As planets grow, the exchange of angular momentum with the gaseous component of the protoplanetary disc produces a net torque resulting in a variation of the planet's semi-major axis. For low-mass planets not able to open a gap in the gaseous disc this is known as type I migration. Pioneer works studied this phenomenon in isothermal disc, finding in general fast and inward migration. In the last years several improvements have been made extending the study of type I

migration rates to non-isothermal discs. Recently, it was demonstrated that inward migration could be slowed down and even reversed if the planet's luminosity due to accretion of solids is considered. In this poster we present results of the planet formation process incorporating, and comparing, updated type I migration rates for non-isothermal discs. We also analyse the role of the planet's luminosity on those rates and its impact on planet formation.

Mickey M Rosenthal

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Oral presentation

Title: Measuring the Orbital Parameters of Radial Velocity Systems in Mean Motion Resonance a Case Study of HD 200964

Abstract: The presence of mean motion resonances between observed exoplanets is an important diagnostic for the early formation history of these systems. However, the strong dynamical interaction that results from mean motion resonance can greatly complicate determination of the underlying orbital parameters, particularly for systems observed through the radial velocity technique. Mean motion resonance can allow planets to remain stable in regions of phase space where strong planet-planet interactions would otherwise destabilize the system. Operationally, this means that fits to the parameters of resonant systems without stability requirements often include, or even favor, unstable configurations. In addition, the extra frequencies added by the dynamical interaction between the planets can also greatly broaden the posterior distribution of orbital parameters when compared to a purely Keplerian fit. Furthermore, libration of the resonant angle and dynamical interaction between the planets introduces another, long period variation into the observed RV signal, complicating analysis of the periods of the planets in the system. In this talk, I will highlight these challenges and discuss ways in which they can be overcome, using the planetary system around the star HD 200964 as a case study. While this system was originally published as a 4:3 mean motion resonance, in our analysis we find that the system is well fit by a 3:2 and 7:5 mean motion resonance in addition to the 4:3.

Qi Shu

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Poster presentation

Title: Free-floating massless particles in star clusters

Abstract: We present a study on the dynamics of massless particles (MLPs) in star clusters. MLPs, such as comets, asteroids, planetesimals, and free-floating planets, are continuously injected into the intra-cluster environment by their host stars. We carry out numerical simulations to investigate the dynamical evolution of MLP populations in star clusters, including their ejection rates and capture rates, using NBODY6++GPU-ML, a modified version of the N-body simulation code NBODY6++GPU. Unlike stars, MLPs do not participate in the mass segregation process. Instead, MLPs primarily follow the gravitational potential of the star cluster, which gradually decreases due to stellar ejections and stellar evolution. The decrease in the number of MLPs is stronger for clusters with a stronger external tidal field, and for clusters with a smaller initial stellar mass range. MLPs are regularly captured into wide, highly-eccentric star-MLP binaries, most of which are disrupted within 10 Myr. These systems occasionally have periastron distances small enough to allow dynamical interaction between the MLP and an existing planetary system, if present. As a star cluster evolves, the population of (initially) free-floating MLPs evolves to a dynamical equilibrium in which a fraction 10-4 of the MLPs is part of a star-MLP binary. Under the assumption that other stars have similar formation histories and cometary ejection rates as our Solar system, we estimate that young star clusters contain large numbers (1017) free-floating comets, and that each star typically hosts 105 captured comets at a given time. We speculate that our own Solar system, which may have formed in a star cluster of similar size, hosts a comparable number of captured exocomets in the Oort cloud.

Manu Stalport

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Poster presentation

Title: Orbital stability as a way to refine multiplanetary systems

Abstract: As of today, thousands of exoplanets have been detected. However, for most of them, their physical and orbital parameters are only poorly constrained. This is especially the case for the eccentricity which is very challenging to measure for low mass exoplanets.

Nonetheless, in multiplanetary systems, certain sets of solutions can lead to orbital instabilities that significantly alter the system architecture (ejection of a planet, collision...) on a short timescale. Stability criteria can thus be used to add constraints on the planets' parameters.

Our aim is to develop a rigorous method to include properly stability criteria in a Bayesian framework. Using fast chaos indicators, we synthesize the stability information into a probability of observing the system for each given realization. This probability is then used to refine the posterior distributions of parameters.

Such a refinement would bring several advantages. Indeed, the method will potentially provide an important tool to better understand the role stability plays in the architecture of planetary systems. Furthermore, it may drastically reduce the uncertainties on the parameters' estimation.

Stephan Stock

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Oral presentation

Title: A tightly packed multiplanetary system around an active M dwarf

Abstract: The CARMENES survey targets around 300 M dwarfs stars to search for Earth-sized planets in the habitable zones by using the radial velocity technique. Many M dwarfs harbor tightly packed systems of Earth-mass planets on rather short orbits, which is very interesting from the dynamical viewpoint. Understanding the dynamics in such systems can help to constrain the formation of the system in particular as well as planet formation in general. We present our current results regarding one such system whose true configuration is still debated in the literature. We have taken additional HARPS and CARMENES data in order to solve any remaining ambiguities regarding the planetary configuration. We go on to perform

a detailed dynamical analysis of the system, which will help to provide constrains on eccentricities, inclinations, planetary masses and possible formation scenarios for the planets of the system. In particular, we would like to assess whether the system, whose planetary periods are almost multiples of each other, is truly in resonance. We will also shortly discuss the problems we have encountered regarding the dynamical analysis of tightly packed systems around active M dwarfs using radial velocity data and which tools might be necessary in the future to tackle this problems.

Jean Teyssandier

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Oral presentation

Title: Formation of hot Jupiters through secular chaos and dynamical tides

Abstract: The population of giant planets on short-period orbits (hot Jupiters) can potentially be explained by some flavours of high-eccentricity migration. In this talk I will review new developments regarding one such mechanism involving secular chaos, in which secular interactions between at least three giant planets push the inner planet to a highly eccentric orbit, followed by tidal circularization and orbital decay. In addition to the equilibrium tidal friction, I will discuss the effects of dissipation due to dynamical tides that are excited inside the giant planet. This improved model of tides allows for stronger dissipation and can save planets from tidal disruption. This study represents the first large-scale attempt at characterizing the efficiency of forming hot Jupiters via secular chaos. I will discuss how the predictions of this mechanism regarding the properties of hot Jupiters (period distribution, spin-orbit angle...) compare with observations.

Trifon Trifonov

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Oral presentation

Title: Dynamical characterization and prospects of habitability for the GJ 1148 system

Abstract: We present a dynamical analysis for the GJ 1148 multi-planetary system. This system is composed of a nearby M dwarf star and two moderately eccentric Saturn mass companions, whose orbital periods are 41.3 and 532.6 days. The two planets were detected using precise radial velocity measurements taken over the past 18 years with the state-of-the-art spectrographs Keck-HIRES and CARMENES. We conducted detailed statistical and dynamical analyses of the Doppler data and studied the long-term stability and dynamical architecture of the system. Systems of the type of GJ 1148 are very rare. Together with the enigmatic GJ 876 system, the two are the only M dwarf planetary systems known to host a pair of giant planets. Therefore, shedding light on the dynamical architecture of the GJ 1148 system is an important milestone for probing planetary formation and evolution scenarios. Since GJ 1148 b is orbiting in the Habitable Zone around its host star the prospects of potentially stable habitable moons will be discussed.

Trifon Trifonov

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Poster presentation

Title: Transit and Radial velocity Interactive Fitting tool for Orbital analysis and N-body simulations: The Exo-Striker

Abstract: I present a new very powerful and fast GUI tool for exoplanet orbital analysis and N-body simulations. It uses a brand new RV fitting library called "RV-mod", which can model the Stellar reflex motion caused by dynamically interacting planets in multi-planetary systems. The Exo-Striker tool offers a broad range of tools for detailed analysis of transit and Doppler data. Some of the key features of the tool are:
– Power spectrum analysis (GLS for RVs & TLS for transit data)
– Keplerian and dynamical RV modeling of multi-planet systems
– Joint Transit and RV modeling
– Gaussian Processes modeling

– Parameter optimization (Simplex, LM, TNC, Powell and many more)
– MCMC (via *emcee*) and Nested sampling (via *dynesty*)
– Long-term stability check of multi-planet systems
– Easy and very flexible fully interactive and very fast plotting widgets
– Import/export of working sessions
– Export of ready-to-use LaTeX tables with best-fit parameters, errors and statistics
– Text editor, Bash-shell and fully Integrated Jupyter widget shell
– RVmod can be used as stand alone standard Python library (e.g. without the Exo-Striker GUI, simply as *"import RVmod as rv"*)

The tool is cross-platform compatible (MAC OS, Linux, Windows) and it combines Fortran efficiency and Python flexibility. Currently, the tool is still under active development, but is very close to a "Version 1" release. It can be found on the github under https://github.com/3fon3fonov/trifon.

Dimitri Veras

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Invited Talk

Title: Violent dynamics in planetary systems around dying stars

Abstract: Understanding the full life cycle of a planetary system requires investigating how it dies just as how it was formed. When the host star evolves beyond its Sun-like "main sequence" state, then the planetary system will be reshuffled, excited and partly pulverised. The resulting dynamical applications to planets, moons, asteroids and comets are numerous, covering gravitational scattering, mean motion resonances, secular resonances, the variable-mass two-body and three-body problems, binary star interactions, radiative spin-up from the YORP effect, radiative shifts from the Yarkovsky effect, atmospheric evaporation, star-planet tidal interactions, Galactic tides, magnetic fields, stellar flybys, debris disc formation and evolution, and accretion processes. Recent high-profile observations of these systems present a need for dynamicists to keep pace and explore many outstanding issues, which I will present.

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Poster presentation

Title: Reverse Population Synthesis for Observed Planets around Evolved Stars

Abstract: With the growing number of exoplanets detected around evolved stars, it becomes evident that the planet population around giant stars possesses different properties than the population around main-sequence stars, especially regarding the period distribution. We investigate the origin of these differences by studying the effect of stellar post-main-sequence evolution on the orbital architecture of the planetary systems detected around evolved stars within our RV survey of G and K giants (Reffert et al. 2015). We use evolutionary tracks to reconstruct the host stars' past evolution and simulate the combined effects of tidally induced orbital decay and mass loss induced orbital expansion on the semi-major axes and eccentricities of the observed planets. Running our simulations backwards in time allows us to synthesize the planet population as it was on the main-sequence and to compare it to the observed planet population around less massive main-sequence stars.

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Oral presentation

Title: Pure Three-body and Double Two-body Resonances in Multi-planet Systems

Abstract: Mean-motion resonances (MMR) play an important role in some exoplanet systems. MMR between 2 planets have been studied extensively. MMR involving 3 or more planets and 3-body/Laplace resonance are more difficult to study, but the need to understand them is growing due to the discov- ery of multiplanet systems in chains of 3-body resonances (e.g., Kepler-60, Kepler-80, Kepler-223, TRAPPIST-1) in recent years. 3-body resonances can be classified as double resonance (3-body resonance with librating 2-body resonance angles) and pure 3-body resonance (3-body resonance with circulating 2-body resonance angles). It is unclear which type of 3-body resonance is involved in the observed systems due to uncertainties in the eccentricities and longitudes of periapse of the orbits. The goal of our study is to understand the differences between double resonance and pure 3-body resonance. We use as an example the triplet composed of planets d, e, and f in the TRAPPIST-1 system, which are in a double 3:2 period commensurability.

We find that the departure of the period ratio of the inner planet pair from exact commensurability automatically determines the departure of the outer pair (and vice versa), if the planets are in either type of 3-body resonance. The departures from exact commensurability also determines the forced eccentricities of all 3 planets. We show that by applying artificial forces, such as eccentricity excitation, we can produce either a shift in forced eccentricities or a growth in free eccentricities. The system can change from double resonance to pure 3-body resonance if the free eccentricity of the middle planet grows to exceed its forced eccentricity. Pure 3-body resonance can be preserved up to very high free eccentricity (few tens of the forced eccentricity), when the forced eccentricity is small.

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Oral presentation

Title: Planet formation in discs with inclined binary companions: can primordial spin-orbit misalignment be produced?

Abstract: Many hot Jupiter (HJ) systems have been observed to have their stellar spin axis misaligned with the planet's orbital angular momentum axis. The origin of this spin-orbit misalignment and the formation mechanism of HJs remain poorly understood. A number of recent works have suggested that gravitational interactions between host stars, protoplanetary discs, and inclined binary companions may tilt the stellar spin axis with respect to the disc's angular angular momentum axis, producing planetary systems with misaligned orbits. These previous works considered idealized disc evolution models and neglected the gravitational influence of newly formed planets. In this paper, we explore how disc photoevaporation and planet formation and migration affect the inclination evolution of planet-star-disc-binary systems. We take into account planet-disc interactions and the gravitational spin-orbit coupling between the host star and the planet. We find that the rapid depletion of the inner disc via photoevaporation reduces the excitation of stellar obliquities. Depending on the formation and migration history of HJs, the spin-orbit coupling between the star and the planet may reduces and even completely suppress the excitation of stellar obliquities. Our work constrains the formation/migration history of HJs. On the other hand, planetary systems with cold Jupiters or close-in super-earths may experience excitation of stellar obliquities in the presence of distant inclined companions.
