Exoplanet Demographics Conference
November 9-13, 2020
Monday Talk Abstracts

History of Exoplanet Demographics

The History of Exoplanet Demographics: Observation and Theory - Scott Gaudi (The Ohio State University) and Ruth Murray-Clay (UCSC)

Inner Planetary System Demographics

The Kepler Transiting Exoplanet Sample: Physical Properties - Jason Rowe (Bishop's University)

The 4-year Kepler Mission has discovered at least 4300 validated exoplanets and exoplanet candidates. Measuring reliable, repeatable and trustworthy physical properties and the orbital environment of these planets is fundamental towards understanding the underlying demographics. Fundamental properties include planetary radius, orbital period, orbital inclination, incident flux, eccentricity and transit-timing-variations (TTVs). Reliable posterior distributions require assessment of the underlying stellar parameters and the applied methodology to model a planetary transit in the presence of instrumental and astrophysical noise. This talk will review the evolution of planetary properties from the Kepler sample beginning with the first Kepler-Object-of-Interest (KOI) catalogues (Borucki, et al 2011) through subsequent major data releases including Q6, Q8, Q12, DR24, DR25 and recent work based on state-of-the-art noise models and significant improvements in stellar priors now available from the astrometric GAIA mission and ground-based spectroscopic follow-up. The complication of a non-uniform stellar disk, integrated disk stellar variability and non-Gaussian instrumental artifacts such as readout cross-talk affects extracted parameters and introduces potential biases impacting inferred physical properties such as planet radius and recovery statistics such as signal-to-noise. Methods to fit transit models to observations and recover posteriors can bias reported distributions, such as orbital inclination. The assessment and inclusion of TTVs improves precision of mean-orbital periods and precision transit shape measurements. In the short decade since the first Kepler planet physical properties were published the field has seen a transformational change in our approach to transit modelling and have led to a new uniform reduction of the Kepler sample. A new Kepler properties catalogue will be presented that takes into account our best knowledge of stellar parameters and best transit model methodologies.

Forward Modeling the Distribution of Intrinsic Architectures of Inner Planetary Systems - Eric Ford (Penn State)

I propose to review recent progress in characterizing the intrinsic distribution of inner planetary architectures (P <~ 1 year) based primarily on observations from NASA's Kepler mission. I will draw from over a dozen papers to compare and contrast results for the number of planets per inner planetary system, the relationship of planet sizes and orbital periods within a system, potential causes of the apparent "Kepler dichotomy" and "peas-in-a-pod" phenomena, and the putative correlations of eccentricities and/or inclinations with multiplicity. Then, I will summarize how forward modeling of both the intrinsic population and selection effects has improved our understanding of each of the above issues, along with the implications for planet formation theory. I will discuss the current limits of our knowledge of the distribution of inner planetary architectures due to degeneracies from using solely transit observations and/or the size of the Kepler sample. Finally, I will describe how precision radial velocity surveys can test state-of-the-art population models by detecting and characterizing non-transiting planets.

Detection Limits and Occurrence Rates of the CARMENES M Dwarf Survey - Silvia Sabotta (Thuringian State Observatory)

The CARMENES radial velocity survey is one of the most extensive radial velocity surveys for M dwarfs. It has has been monitoring a sample of more than 300 low-mass stars for more than 4 years and discovered more than 30 exoplanets. This data set holds a treasure for planet demographics studies that waits to be uncovered. As the survey is still ongoing, we present our analysis of a subset of 125 stars that we stopped observing for various reasons. In my talk, I will present a statistical analysis of the past survey and show how we identified and corrected for various biases.

The planetary occurrence rates we derived provide important clues for our understanding of the formation mechanisms of planetary systems around low-mass stars.

The Typical Planets Discovered by Transit Surveys and Their Implications for Planet Formation and Evolution - Kevin Schlaufman (Johns Hopkins University)

All mass--radius relations for low-mass planets published to date have been affected by observational biases. Since planet occurrence and primordial atmospheric retention probability increase with period, the ``typical'' planets discovered by transit surveys may bear little resemblance to the short-period planets sculpted by atmospheric escape ordinarily used to calibrate mass--radius relations. An occurrence-weighted mass--radius relation for the typical low-mass planets in the Galaxy observed so far by transit surveys requires both typical Earth-mass and Neptune-mass planets to have a few percent of their mass in H/He atmospheres to explain their observed radii. Unlike the terrestrial planets in our own solar system that finished forming long after the protosolar nebula was dissipated, these Earth-mass planets discovered in transit surveys must have formed early in their systems' histories. The existence of significant H/He atmospheres around Earth-mass planets confirms an important prediction of the core-accretion model of planet formation. It also implies that such planets can retain their primordial atmospheres and requires an order-of-magnitude reduction in the fraction of incident XUV flux converted into work usually assumed in photo-evaporation models. In contrast to Uranus and Neptune, which have at least 10% of their mass in H/He atmospheres, the typical Neptune-mass planets discovered in transit surveys are H/He poor. The implication is that they must have formed in much hotter parts of their parent protoplanetary disks than Uranus and Neptune's formation location in the protosolar nebula.

A Uniform Sample of K2 Planets and Early Occurrence Results - Jon Zink (UCLA)

Up to this point the Kepler mission data has been considered the gold standard for exoplanet occurrence rates. However, 18 campaigns of data, sampling a variety of Galactic latitudes, were collected following the malfunction that lead to the end of the Kepler prime mission. These fields provide a unique opportunity to understand how exoplanet occurrence is affected by Galactic latitude, stellar metallicity, and stellar age. With a fully automated pipeline now able to detect and vet transit signals in K2 data, we can measure the sample completeness and reliability. Doing so, we present the first uniform analysis of small transiting exoplanet occurrence outside of the Kepler field and find the FGK samples are relatively consistent. This early result also provides supporting evidence for metallicity driven planet formation. With all of the campaigns now fully processed, we will make public the occurrence rate tools needed to analyze this new rich dataset.

Outer Planetary System Demographics

Planet Demographics from the Outside-in: Properties of Long-period Giant Planets from Direct Imaging Surveys - Brendan Bowler (The University of Texas at Austin)

Direct imaging is sensitive to the outskirts of young planetary systems. About 15 substantial high-contrast imaging surveys have been completed in as many years, including recent results from second-generation instruments with extreme adaptive optics capabilities. Despite the low intrinsic occurrence rate of giant planets between 10-100 AU, these campaigns have now amassed large enough samples to tease out correlations between planet frequency and other parameters such as stellar host mass and presence of a debris disk. Additionally, the ensemble of discoveries are providing the statistical leverage to constrain how long-period planets are distributed in mass and separation. In this review I will provide an overview of giant planet demographics uncovered by direct imaging surveys, including both the implications and limitations of these measurements. I will also highlight the connection of imaged planets with those flanking this population at closer separations (from long-baseline radial velocity programs) and at much wider separations (from seeing-limited infrared surveys). Altogether these results are jointly helping to constrain the demographics of giant planets spanning five decades in orbital distance.

Testing the Core Accretion Theory with Exoplanet Demographics from Microlensing and Radial Velocities - David Bennett (NASA GSFC/Univ. of Maryland)

The formation of planets beyond the snow line is an important aspect of the core accretion theory. While the snow line is well beyond the habitable zone, it is thought that the planet population beyond the snow line can influence the habitability of planets by controlling delivery of volatiles, such as water, to planets in the habitable zone. However, these planets are largely undetectable by the transit method. The microlensing method has the highest sensitivity to low-mass planets beyond the snow line, while the radial velocity method is sensitive to giant planets over a wide range of orbital separations. I present a joint Bayesian analysis of microlensing and radial velocity demographics studies to investigate the demographics of wide-orbit planets. This includes an investigation of what role, if any, the runaway gas accretion process has on the final distribution of planets beyond the snow line.

Cold Planet Demographics from 12 years MOA-II Microlensing Survey Data - Daisuke Suzuki (Osaka University)

The Microlensing Observations in Astrophysics (MOA) collaboration has been conducting a high cadence microlensing survey toward the Galactic bulge since 2006 by using a dedicated 1.8m MOA-II telescope in New Zealand. They find 5-10 microlensing planets per year with other microlensing survey / follow-up teams. Previously, we derived a planetary mass-ratio function from the 6yrs MOA-II microlensing survey data in 2007 – 2012 including 23 planets and found a break around the mass-ratio of 0.0001, instead of single power law mass-ratio function used before (Suzuki et al. 2016). However, the slope of the mass-ratio function for the planets with mass-ratio below the break are not well determined because the planets sample below the break was not large enough. We extend this study by using another set of 6yrs survey data in 2013 – 2018. The expected number of planets in the total sample is roughly 50. In this talk, we will show the preliminary result for the updated mass-ratio function for cold planets, as well as the dependency on the separation (projected star-planet distance normalized by the Einstein radius). Also, we will briefly introduce the PRIME project that is expected to start the first dedicated NIR microlensing survey in 2021, as a precursor of the microlensing survey by Roman Space Telescope.

The Gemini Planet Imager Exoplanet Survey: Giant Planet and Brown Dwarf Demographics from -100 AU - Eric Nielsen (New Mexico State University)

The Gemini Planet Imager Exoplanet Survey (GPIES) has observed 521 young, nearby stars, making it one of the largest, deepest direct imaging surveys for giant planets ever conducted. With detections of six planets and four brown dwarfs, including the new discoveries of 51 Eridani b and HR 2562 B, GPIES also has a significantly higher planet detection rate than any published imaging survey. Our analysis of the uniform sample of the first 300 stars reveals new properties of giant planets (>2 MJup) from 3-100 AU. We find at >3 sigma confidence that these planets are more common around high-mass stars (>1.5 solar masses) than lower-mass stars. We also present evidence that giant planets and brown dwarfs obey different mass functions and semi-major axis distributions. Our direct imaging data imply that the giant planet occurrence rate declines with semi-major axis beyond 10 AU, a trend opposite to that found by radial velocity surveys inside of 10 AU; taken together, the giant planet occurrence rate appears to peak at 3-10 AU. All of these trends point to wide-separation giant planets forming by core/pebble accretion, and brown dwarfs forming by gravitational instability.

The Demographics of Young Giant Exoplanets Below 300 AU from the SPHERE Infrared Survey for Exoplanets (SHINE) - Arthur Vigan (CNRS /LAM)

The SPHERE infrared exoplanet (SHINE) project is a 500-star survey performed with VLT/SPHERE for the purpose of directly detecting new sub-stellar companions and understand their formation and early evolution. We present the results of a first statistical analysis for a sub-sample of 150 stars spanning spectral types from B to M, representative of the full SHINE sample, which constrain the frequency of sub-stellar companions with masses between 1 and 75 MJup and semi-major axes between 5 and 300 au. Based on the detection limits obtained for each star and the 13 detections in the sample, we use a Markov chain Monte Carlo analysis to compare our observations to (1) a parametric model based on observational constraints, and (2) numerical models that combines state-of-the-art core accretion and gravitational instability planet population synthesis. Using our parametric model, we derive the frequency of sub-stellar companions around BA, FGK and M stars and we demonstrate that a planet-like formation pathway probably dominates the mass range from 1 to 75 MJup for companions around BA stars, while for M dwarfs brown dwarf binaries dominate detections. Using our population model, and restricting our sample to FGK stars, we derive a frequency that is consistent with the parametric model and we show that qualitatively, the contribution of the core accretion part of the model seems enhanced over the gravitational instability part. Finally, we conclude with the implications of our results in the broader context of giant planet formation theory.