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224th Meeting of the American Astronomical Society

May 31 - 05, 2014

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Saturday, May 31, 2014

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Sunday, June 01, 2014

You have nothing scheduled for this day

Monday, June 02, 2014

You have nothing scheduled for this day

Tuesday, June 03, 2014

Time	Session Info
10:00 AM-11:30 AM, America Ballroom North/Central (Westin Copley Place), **On the Shoulders of Giants: Planets Beyond the Reach of Kepler I: What We Know Today and What We Would Like to Learn**	
10:00-10:05 AM	**201.01. Planets Beyond the Reach of Kepler - Introduction** S.C. Unwin
10:05-10:30 AM	**201.02. Studying Extrasolar Planets with WFIRST** D.N. Spergel
10:30-10:55 AM	**201.03. Theory of giant planet atmospheres and spectra** A.S. Burrows
10:55-11:15 AM	**201.04. Observed & Predicted Debris Disks Structures Beyond the Reach of Kepler** C.C. Stark
11:15-11:30 AM	**201.05. Theoretical Albedo Spectra of Exoplanet Direct Imaging Targets** N. Lewis; M.S. Marley; J.J. Fortney
2:00 PM-3:30 PM, America Ballroom North/Central (Westin Copley Place), **On the Shoulders of Giants: Planets Beyond the Reach of Kepler II: Demographics**	
2:00-2:20 PM	**210.01. Demographics of Giant Planets--Insights from Theory** R. Murray-Clay
2:20-2:40 PM	**210.02. Characterizing Cold Giant Planets in Reflected Light: Lessons from 50 Years of Outer Solar System Observation and Exploration** M.S. Marley; H.B. Hammel
2:40-3:00 PM	**210.03. The Occurrence Rate of Giant Planets around M-dwarf Stars** J.R. Crepp; B. Montet; J.A. Johnson; A. Howard; G.W. Marcy
3:00-3:15 PM	**210.04. Planet frequency beyond the snow line from MOA-II microlensing survey** D. Suzuki
3:15-3:30 PM	**210.05. Free-floating planets from microlensing** T. Sumi

Wednesday, June 04, 2014

Time	Session Info
10:00 AM-11:30 AM, America Ballroom North/Central (Westin Copley Place), **On the Shoulders of Giants: Planets Beyond the Reach of Kepler III: Ground-based Imaging and Spectroscopy**	
10:00-10:15 AM	**301.01. Detecting and Characterizing Exoplanets with Direct Imaging from the Ground** B. Biller
10:15-10:30 AM	**301.02. The Gemini Planet Imager** B. Macintosh
10:30-10:45 AM	**301.03. SEEDS - Direct Imaging of Exoplanets and Their Forming Disks with the Subaru Telescope** M. Tamura
10:45-10:55 AM	**301.04. Tracing Planetary System Architecture with Debris Disk Imaging** G. Bryden
10:55-11:10 AM	**301.05. Overview of future ground and space imaging capabilities** R. Soummer
11:10-11:20 AM	**301.06. Pushing the radial velocity accuracy of HARPS and HARPS-N.** X. Dumusque
11:20-11:30 AM	**301.07. First science results from the K2 mission** T. Barclay
2:00 PM-3:30 PM, America Ballroom North/Central (Westin Copley Place), **On the Shoulders of Giants: Planets Beyond the Reach of Kepler IV: The Near Future**	
2:00-2:20 PM	**311.01. Overview of WFIRST-AFTA Mission Capabilities** N. Gehrels
2:20-2:30 PM	**311.02. Mass Measurements for Microlens Planets with WFIRST/AFTA** J.C. Yee
2:30-2:40 PM	**311.03. WFIRST-AFTA: What Can We Learn by Detecting Thousands of Cold Exoplanets via Microlensing?** M. Penny
2:40-2:55 PM	**311.04. Capabilities of WFIRST-AFTA for coronagraphic imaging of exoplanets** W.A. Traub
2:55-3:10 PM	**311.05. Observing Other Worlds With JWST** C.A. Beichman
3:10-3:20 PM	**311.06. Exo-S: A Probe-scale Space Mission to Directly Image and Spectroscopically Characterize Exoplanetary Systems Using a Starshade and Telescope System** S. Seager; W.C. Cash; N.J. Kasdin; W.B. Sparks; M.C. Turnbull; M.J. Kuchner; A. Roberge; S. Domagal-Goldman; S. Shaklan; M. Thomson; D. Lisman; S. Martin; E. Cady; D. Webb

3:20-3:30 PM	**311.07. Exo-C: A probe-scale space mission to directly image and spectroscopically characterize exoplanetary systems using an internal coronagraph** K.R. Stapelfeldt; M.P. Brenner; K. Warfield; R. Belikov; P. Brugarolas; G. Bryden; K.L. Cahoy; S. Chakrabarti; F. Dekens; R. Effinger; B. Hirsch; A. Kissil; J.E. Krist; J. Lang; M.S. Marley; M.W. McElwain; V. Meadows; J. Nissen; J. Oseas; G. Serabyn; E. Sunada; W.A. Traub; J.T. Trauger; S.C. Unwin

Thursday, June 05, 2014

You have nothing scheduled for this day

Final ID: 201.01

Planets Beyond the Reach of Kepler - Introduction

S. C. Unwin; [1];
1. JPL, Pasadena, CA, United States.

Abstract (2,250 Maximum Characters): What kind of planets lie at orbit radii of 1-2 AU - beyond the reach of Kepler? In the last two decades we have explored a sample of RV-detected planets, discovered distant planets with microlensing, and several hot young planets at large radii have been detected by direct imaging, as well as the debris disks that provide clues to formation and evolution. In these 4 sessions, we explore the near future, and how we can expect to learn much more about the demographics and properties of cold outer planets. AFTA-WFIRST will open up this area, with a microlensing survey to probe the population of long-orbit planets, and coronagraphy to take images and spectra of large planets in orbits at a few AU.

Final ID: 201.02

Studying Extrasolar Planets with WFIRST

D. N. Spergel; [1];

1. Princeton Univ. Obs., Princeton, NJ, United States.

Abstract (2,250 Maximum Characters): The WFIRST mission will be a powerful tool for studying extrasolar planets. Through observations of gravitational microlensing, the mission will probe the demographics of extrasolar planetary systems. Its coronagraph will enable imaging and spectroscopic study of nearby planets. It will also be able to complement GAIA's astrometric measurements of masses and orbits of nearby planets.

Final ID: 201.03

Theory of giant planet atmospheres and spectra

A. S. Burrows; [1];
1. Princeton University, Princeton, NJ, United States.

Abstract (2,250 Maximum Characters): Giant exoplanet atmospheres have now been studied by transit spectroscopy, spectroscopy and photometry at secondary eclipse, photometric light curves as a function of orbital phase, very high-resolution spectroscopic velocity measurements, and high-contrast imaging. Moreover, there is a correspondence between brown dwarf and giant planet atmospheres and spectra that has been profitably exploited for many years to better understand exoplanets. In this presentation, I endeavor to review the information extracted by these techniques about close-in giant exoplanet compositions and temperatures. Then, I will summarize the expected character of the spectra, light curves, and polarizations of the objects soon to be studied using high-contrast imaging by GPI, SPHERE, WFIRST-AFTA, and Subaru/HiCIAO as a function of mass, age, Keplerian elements, and birth properties (such as entropy). The goal will be to frame the theoretical discussion concerning what physical information can be gleaned in the next years about giant planet atmospheres by direct (or almost direct) imaging and characterization campaigns, and their role as stepping stones to the even more numerous sub-Neptunes, super-Earths, and Earths.

Final ID: 201.04

Observed & Predicted Debris Disks Structures Beyond the Reach of Kepler

C. C. Stark; [1];

1. NASA Goddard Space Flight Center, Greenbelt, MD, United States.

Abstract (2,250 Maximum Characters): Over the last several years our theoretical understanding of debris disks has evolved significantly. A number of new computational advances, in the realms of disk modeling and data analysis, have deepened our knowledge of structures in debris disks. More than ever, we are acutely aware of the many sources of structures--be they gravitational perturbations by planets, other external perturbations, or more subtle non-perturbative sources. At the same time, new observatories, instruments, and observation strategies have provided a rich data set for debris disk theorists to test and constrain their models. I will discuss our current understanding of structures in debris disks. I will show the wide array of structures that planets can dynamically sculpt and comment on how imaging of these structures with future missions may constrain the underlying planetary system. I will also present a cautionary tale of interpreting debris disk structures as planetary perturbations, show how our appreciation of alternative sources of structures has grown, and present new methods for disentangling true density structures from projection and scattering effects.

Final ID: 201.05

Theoretical Albedo Spectra of Exoplanet Direct Imaging Targets

N. Lewis; [1]; *M. S. Marley;* [2]; *J. J. Fortney;* [3];
1. MIT, Cambridge, MA, United States.
2. NASA/Ames, Moffett Field, CA, United States.
3. UCSC, Santa Cruz, CA, United States.

Abstract (2,250 Maximum Characters): Space-based coronagraphic telescopes currently under study would enable direct imaging of scattered light from giant exoplanets in orbits beyond 1 AU from their host stars. Considering the known radial-velocity planets alone, directly imaged planets will encompass a broad range of atmospheric properties, including a number of possible cloud species. Here we present theoretical albedo spectra (0.35 to 1 micron) for the most favorable targets for spaced-based coronagraph observations (good angular resolution and contrast) from the current population of known radial-velocity planets. We consider a range of internal temperatures and atmospheric metallicities as constrained by the system ages and planetary minimum masses. Additionally, we construct a grid of theoretical Jupiter and Neptune-like exoplanets around a variety of host stars at distances of 1, 3, and 5 AU. From this grid, we identify spectral and photometric signatures associated with planetary gravity, cloudiness, and composition that can used to select promising new targets as they are discovered. This work will help to guide the development and initial interpretation of a range of direct imaging exoplanet studies that will shed new light on important physical processes underlying giant planet formation and evolution.

Final ID: 210.01

Demographics of Giant Planets--Insights from Theory

R. Murray-Clay; [1];
1. Harvard-Smithsonian Center for Astrophysics, Cambridge, MA, United States.

Abstract (2,250 Maximum Characters): The demographics of giant planets arise from a combination of the physical properties and evolution of protoplanetary disks, the planet formation process itself, and the dynamical evolution of planets post-formation. In this talk, I will review each of these contributions to giant planet demographics with an emphasis on how future discoveries can be used to separate and constrain their effects. I will particularly discuss how giant planet demographics will constrain the mechanism by which giant planets form, an old theoretical problem on the cusp of an observational breakthrough.

Final ID: 210.02

Characterizing Cold Giant Planets in Reflected Light: Lessons from 50 Years of Outer Solar System Observation and Exploration

M. S. Marley; [1]; *H. B. Hammel;* [2];
1. NASA Ames Research Center, Moffett Field, CA, United States.
2. AURA, Washington, DC, United States.

Abstract (2,250 Maximum Characters): A space-based coronagraph, whether as part of the WFIRST/AFTA mission or on a dedicated space telescope such as Exo-C or -S concepts, will be able to obtain photometry and spectra of multiple giant planets around nearby stars, including many known from radial velocity detections. Such observations will constrain the masses, atmospheric compositions, clouds, and photochemistry of these worlds. Giant planet albedo models, such as those of Cahoy et al. (2010) and Lewis et al. (this meeting), will be crucial for mission planning and interpreting the data. However it is equally important that insights gleaned from decades of solar system imaging and spectroscopy of giant planets be leveraged to optimize both instrument design and data interpretation. To illustrate these points we will draw on examples from solar system observations, by both HST and ground-based telescopes, as well as by Voyager, Galileo, and Cassini, to demonstrate the importance clouds, photochemical hazes, and various molecular absorbers play in sculpting the light scattered by solar system giant planets. We will demonstrate how measurements of the relative depths of multiple methane absorption bands of varying strengths have been key to disentangling the competing effects of gas column abundances, variations in cloud height and opacity, and scattering by high altitude photochemical hazes. We will highlight both the successes, such as the accurate remote determination of the atmospheric methane abundance of Jupiter, and a few failures from these types of observations. These lessons provide insights into technical issues facing spacecraft designers, from the selection of the most valuable camera filters to carry to the required capabilities of the flight spectrometer, as well as mission design questions such as choosing the most favorable phase angles for atmospheric characterization.

Final ID: 210.03

The Occurrence Rate of Giant Planets around M-dwarf Stars

J. R. Crepp; [1]; *B. Montet;* [2, 3]; *J. A. Johnson;* [3]; *A. Howard;* [4]; *G. W. Marcy;* [5];
1. Notre Dame, South Bend, IN, United States.
2. California Institute of Technology , Pasadena, CA, United States.
3. Harvard, Cambridge, MA, United States.
4. U. Hawaii, Honolulu, HI, United States.
5. Berkeley, Oakland, CA, United States.

Abstract (2,250 Maximum Characters): The TRENDS high-contrast imaging program is a dedicated survey based at Keck Observatory that uses high-contrast imaging observations to follow-up stars showing long-term radial velocity accelerations. In this talk, I will present a new technique invented to determine the occurrence rate of gas giant planets on wide orbits (0-20 AU) around low-mass stars.

Final ID: 210.04

Planet frequency beyond the snow line from MOA-II microlensing survey

D. Suzuki; [1];

1. Osaka University, Toyonaka, Osaka, Japan.

Abstract (2,250 Maximum Characters): Ground-based microlensing surveys enable us to detect planets down to Earth masses just beyond the snow line, where temperatures are cold enough for ices to condense. This area of the parameter space is not only out of reach for Kepler but also a key part for planetary formation theory because the surface density of the proto-planetary disk increases by a factor four to five beyond the snow line. It is thus important to understand the planet distribution beyond the snow line. Giant planets located just beyond the snow line also have been discovered by RV and direct imaging, but detecting planets in this parameter space region is still very difficult, in particular as we go down to the super Earth regime.

We present the result of the statistical analysis of microlensing survey data by Microlensing Observations in Astrophysics (MOA) during 2007-2012. In this period, the MOA collaboration issued 3300 microlensing alerts. Using the online data, we reject events with poor quality data and stellar binary lens events. Using these quality criteria, about 1500 single lens and 20 planetary candidate events remain and are used for the statistical analysis. In order to derive the planet abundance, an averaged number of planets per star, beyond the snow line, we calculate the detection efficiency for planets in each selected event. Using the calculated detection efficiencies, we derive the planet mass-ratio function and planet mass function. We calculate the planet abundance within the mass and semi-major axis ranges where our data has sufficient sensitivity to detect planets. We will discuss the planet abundance and compare them with previous microlensing and RV results.

Final ID: 210.05

Free-floating planets from microlensing

T. Sumi; [1];
1. Osaka University, Toyonaka, Osaka, Japan.

Abstract (2,250 Maximum Characters): Gravitational microlensing has an unique sensitivity to exoplanets at outside of the snow-line and even exoplanets unbound to any host stars because the technique does not rely on any light from the host but the gravity of the lens. MOA and OGLE collaborations reported the discovery of a population of unbound or distant Jupiter-mass objects, which are almost twice (1.8_{-0.8}^{+1.7}) as common as main-sequence stars, based on two years of gravitational
microlensing survey observations toward the Galactic Bulge. These planetary-mass objects have no host stars that can be detected within about ten astronomical units by gravitational microlensing. However a comparison with constraints from direct imaging suggests that most of these planetary-mass objects are not bound to any host star. The such short-timescale unbound planetary candidates have been detected with the similar rate in on-going observations and these groups are working to update the analysis with larger statistics. Recently, there are also discoveries of free-floating planetary mass objects by the direct imaging in young star-forming regions and in the moving groups, but these objects are limited to massive objects of 3 to 15 Jupiter masses.They are more massive than the population found by microlensing. So they may be a different population with the different formation process, either similar with that of stars and brown dwarfs, or formed in proto-planetary
disks and subsequently scattered into unbound or very distant orbits. It is important to fill the gap of these mass ranges to fully understand these populations. The Wide Field Infrared Survey Telescope (WFIRST) is the highest ranked recommendation for a large space mission in the recent New Worlds, New Horizons (NWNH) in Astronomy and Astrophysics 2010 Decadal Survey. Exoplanet microlensing program is one of the primary science of WFIRST. WFIRST will find about 3000 bound planets and 2000 unbound planets by the high precision
continuous survey 15 min. cadence. WFIRST can complete the statistical census of planetary systems in the Galaxy, from super-Earths beyond the snow-line to gravitationally unbound planets – a discovery space inaccessible to other exoplanet detection techniques.

Final ID: 301.01

Detecting and Characterizing Exoplanets with Direct Imaging from the Ground

B. Biller; [1, 2];
1. University of Edinburgh, Edinburgh, United Kingdom.
2. MPIA, Heidelberg, Germany.

Abstract (2,250 Maximum Characters): The last decade has yielded the first images of exoplanets, considerably advancing our understanding of the properties of young giant planets. In this talk I will discuss current results from ongoing direct imaging efforts as well as future prospects for detection and characterization of exoplanets via high contrast imaging. Direct detection, and direct spectroscopy in particular, have great potential for advancing our understanding of extrasolar planets. In combination with other methods of planet detection, direct imaging and spectroscopy will allow us to eventually: 1) study the physical properties of exoplanets (colors, temperatures, etc.) in depth and 2) fully map out the architecture of typical planetary systems. Direct imaging has offered us the first glimpse into the atmospheric properties of young high-mass (3-10 M Jup) exoplanets. Deep direct imaging surveys for exoplanets have also yielded the strongest constraints to date on the statistical properties of wide giant exoplanets.

Final ID: 301.02

The Gemini Planet Imager

B. Macintosh; [1];
1. Stanford University, Stanford, CA, United States.

Abstract (2,250 Maximum Characters): The Gemini Planet Imager (GPI) is a next-generation adaptive optics coronagraph designed for direct imaging and spectroscopy of extrasolar planets and polarimetry of circumstellar disks. It is the first such facility-class instrument deployed on a 8-m telescope, designed to achieve contrast levels of up to 10^7. This allows observations of warm self-luminous planets, with masses greater than a Jupiter mass and ages less than a few hundred megayears. GPI will be used for a large-scale survey of 600 nearby young stars, as well as for guest observer science. I will present first-light science results and discuss the scientific capabilities of GPI.

Final ID: 301.03

SEEDS - Direct Imaging of Exoplanets and Their Forming Disks with the Subaru Telescope

M. Tamura; [2, 1];
1. National Astronomical Obs., Mitaka 181-8588, Tokyo, Japan.
2. UTokyo, Bunkyo 113-0033, Tokyo, Japan.

Abstract (2,250 Maximum Characters): SEEDS (Strategic Explorations of Exoplanets and Disks with Subaru) is the first Subaru Strategic Program, whose aim is to conduct a direct imaging survey for giant planets as well as protoplanetary/debris disks at a few to a few tens of AU region around 500 nearby solar-type or more massive young stars devoting 120 Subaru nights for 5 years. The targets are composed of five categories spanning the ages of ~1 Myr to ~1 Gyr. Some RV-planet targets with older ages are also observed. The survey employs the new high-contrast instrument HiCIAO, a successor of the previous NIR coronagraph camera CIAO for the Subaru Telescope. More than 100 nights have already been observed so far without major instrument troubles. We describe the outline of this survey and present its main results. The topic includes (1) detection and characterization of one of the most lowest-mass planet via direct imaging. (2) detection of a super-Jupiter around the most massive star ever imaged, (3) detection of companions around retrograde exoplanet, which supports the Kozai mechanism for the origin of retrograde orbit. We also report (4) the discovery of unprecedentedly detailed structures of more than a dozen of protoplanetary disks and some debris disks. The detected structures such as wide gaps and spirals arms of a Solar-system scale could be signpost of planet.

Final ID: 301.04

Tracing Planetary System Architecture with Debris Disk Imaging

G. Bryden; [1];
1. JPL, Pasadena, CA, United States.

Abstract (2,250 Maximum Characters): Planetary systems can be imaged indirectly via their debris disks - the remnants left over after planets form. Ongoing destruction of asteroids and comets in these disks creates a continual supply of orbiting dust around most Sun-like stars, including our own. In the Solar System such dust is bright enough to be seen with the naked eye - the Zodiacal light. Far-infrared observations by the Spitzer Space Telescope and the Herschel Space Observatory have identified many nearby stars with even brighter orbiting debris, orders of magnitude more than in the Solar System. Because they are so bright, optical imaging of debris disks is much easier than detecting their embedded planets. Such planets can be inferred from disk structure - the inner warp of beta Pic and the sharply defined eccentric rings of Fomalhaut and HD 202628, for example. Resolving individual belts of debris, meanwhile, infers the location of intermediate planets (as in the HR 8799 planetary system) and allows for comparison with the 2-belt architecture of Solar System. Debris disk imaging is particularly well suited toward exploring the outer regions of planetary systems (>10 AU), where mature (cold) planets cannot otherwise be detected. Overall, images of debris disks probe their underlying planetary systems both generally, by mapping the system architecture, and specifically, by determining the location of individual planets.

Final ID: 301.05

Overview of future ground and space imaging capabilities

R. Soummer; [1];
1. Space Telescope Science Institute, Baltimore, MD, United States.

Abstract (2,250 Maximum Characters): This talk serves as an introduction to the session and context of future exoplanet direct imaging capabilities on the ground and in space. The emphasis of the presentation is on short-medium term. On the ground a new generation of instrument (Gemini Planet Imager, VLT-SPHERE, Magellan AO) are beginning their operations with considerable improvement over the previous capabilities. In space, while HST continues operations and provides high-contrast capabilities, JWST will offer several coronagraphs both on the NIRCam and MIRI instrument as well as an aperture masking mode on NIRISS. The possibility of a coronagraphy on WFIRST/AFTA also opens new possibilities for space-based coronagraphy in the medium term.

Final ID: 301.06

Pushing the radial velocity accuracy of HARPS and HARPS-N.

X. Dumusque; [1];

1. Harvard Smithsonian CfA, Cambridge, MA, United States.

Abstract (2,250 Maximum Characters): HARPS and HARPS-N are reaching an incredible radial velocity precision of one meter per second on bright stars. This precision is made possible by the stability of the instrument, and the cross correlation technique that averages out the different sources of noise by stacking together the information of all the observed spectral lines. All possible lines in the spectrum are used, except a few lines sensitive to activity like for example the Ca II H and K lines, and lines close to telluric features. However, the spectra are recorded on a CCD that is not perfect. With the Earth rotating around the Sun, the spectra are shifted back and forth on the CCD and spectral lines are recorded on different sets of pixels as a function of time. I will show some strange behavior of spectral lines that crosses known features on the CCD. Some specific lines show hundreds of meters per second variation on stars that we know are quiet at the meter per second level. By studying the RV variation of each line as a function of time and not considering the ones that exhibit strong variations, it is possible to improve the accuracy of the measurements taken by HARPS and HARPS-N. I will show that this reduces the noise in the RV measurements, which allows us to confirm or reject some planetary detections that are at the limit of the noise.

Final ID: 301.07

First science results from the K2 mission

T. Barclay; [1];
1. NASA Ames Research Center, Mountain View, CA, United States.

Abstract (2,250 Maximum Characters): The K2 mission expands upon Kepler's groundbreaking discoveries in the fields of exoplanets and astrophysics through new and exciting observations. K2 will use an innovative way of operating the spacecraft to observe target fields along the ecliptic for the next 2-3 years. Early science commissioning observations have shown an estimated photometric precision near 400 ppm in a single 30 minute observation, and a 6-hour photometric precision of 80 ppm (both at V=12). Here we present the first science data from the spacecraft. These include observations of transiting planets, eclipsing binaries and pulsating stars.

Final ID: 311.01

Overview of WFIRST-AFTA Mission Capabilities

N. Gehrels; [1];
1. NASA's GSFC, Greenbelt, MD, United States.

Abstract (2,250 Maximum Characters): Wide-Field Infrared Survey Telescope (WFIRST), the top-priority mission in the 2010 Astronomy & Astrophysics Decadal Survey, is now planned to use an already-built 2.4m telescope obtained from the National Reconnaissance Organization. This telescope provides image clarity similar to HST, but with an optical design and array of new-generation H4RG infrared detectors that enables imaging of 100 times the area of HST in a single exposure. This wide-field IR instrument will provide galaxy surveys and supernova monitoring for dark energy studies that are significantly deeper than those planned by other observatories. A microlensing survey of the galactic bulge will give a census of exoplanets that is at larger distance to the Kepler sample. A coronagraph instrument will directly image ice and gas giant planets, and circumstellar disks. There will be significant opportunities for guest observer science. The talk will summarize capabilities and current status.

Final ID: 311.02

Mass Measurements for Microlens Planets with WFIRST/AFTA

J. C. Yee; [1];
1. Harvard Smithsonian CfA, Cambridge, MA, United States.

Abstract (2,250 Maximum Characters): Unlike ground-based surveys, WFIRST/AFTA will be able to systematically measure masses of the lens stars (and hence their planets) for a large number of microlensing events. I will review the methods WFIRST/AFTA will use to measure masses (detection of lens light, microlens parallax, and astrometric microlensing) and present a few examples of how these techniques have been applied to date. These mass measurements are important for understanding the planet population and characterizing structures in the planet mass function beyond the snow line. In addition, they can be used to measure the stellar mass function from black holes to brown dwarfs and unambiguously identifying free-floating planets.

Final ID: 311.03

WFIRST-AFTA: What Can We Learn by Detecting Thousands of Cold Exoplanets via Microlensing?

M. Penny; [1];
1. Department of Astronomy, Ohio State University, Columbus, OH, United States.

Abstract (2,250 Maximum Characters): The WFIRST-AFTA microlensing survey will monitor a few hundred million stars in the Galactic bulge every ~15 minutes to measure the microlensing signatures of thousands of both bound and free-floating planets with masses ranging from super-Jupiters down to that of Ganymede. This huge sample of cold planets will perfectly compliment the sample of warm and hot planets that have been found by Kepler and will be further expanded by TESS and PLATO. I will review the measurements that WFIRST-AFTA will make for each of the planets it finds, and attempt to predict the impact that these will have on our understanding of exoplanet demographics and the planet formation process.

Final ID: 311.04

Capabilities of WFIRST-AFTA for coronagraphic imaging of exoplanets

W. A. Traub; [1];
1. Jet Propulsion Laboratory, Pasadena, CA, United States.

Abstract (2,250 Maximum Characters): The coronagraph on WFIRST-AFTA will be capable of detecting all known radial velocity planets within its range of angular sensitivity, and of characterizing them with photometry and spectroscopy. The coronagraph will also be capable of detecting as-yet unknown exoplanets, from gas giants down to super-Earths around nearby stars, and zodiacal dust disks down to the level of a few times the solar system zodi.

Final ID: 311.05

Observing Other Worlds With JWST

C. A. Beichman; [1];
1. JPL, Pasadena, CA, United States.

Abstract (2,250 Maximum Characters): Exoplanet science is one of the four highest level science themes identified by the JWST project. And indeed, JWST offers dramatic capabilities for characterizing exoplanets with all four of its science instruments. The major observing modes will be coronagraphic imaging, transit photometry, and transit spectroscopy.

Both the near-IR camera, NIRCam, and the mid-IR instrument, MIRI, have coronagraphs which will be able to image directly young planets orbiting nearby stars. While 8-10 m ground-based telescopes equipped with Extreme AO can work at smaller inner working angles, JWST will offer unprecedented sensitivity at 3-20 um outside of ~1” (~4 lam/D at 5 um). At these angular separations JWST will push the detection limit for young planets orbiting at ~10-200 AU down to roughly the mass of Saturn from present-day limits of a few times the mass of Jupiter. This imaging will be carried out using a variety of narrow-, medium- and broad filters to characterize exoplanet orbits and atmospheres. NIRCam and MIRI coronagraphs will also make detailed maps of bright debris disks to investigate their shapes and composition.

All four instruments have photometric and spectroscopic capabilities for transit observations. NIRCam and MIRI will study primary and secondary transits and obtain full orbital light curves in a variety of photometric filters with precision much better than 100 ppm. NIRCam and the Canadian instrument, NIRISS, have grism spectrometers which together span the 1-5 um region at resolutions of a R~300-2,000. NIRSpec has prism and spectrometer modes with spectral resolutions ranging from R=30- 3,000 across the 1-5 um region. MIRI has spectrometer and grism capabilities extending out to 30 um. These spectra and light curves will be used to investigate atmosphere composition, surface gravity, vertical structure, and horizontal flows.

With exoplanet research identified as one of JWST’s four highest level science themes, the exoplanet community should be planning a wide variety of programs that will be strong enough to capture 25% of JWST’s observing time.

Final ID: 311.06

Exo-S: A Probe-scale Space Mission to Directly Image and Spectroscopically Characterize Exoplanetary Systems Using a Starshade and Telescope System

S. Seager; [1]; *W. C. Cash;* [2]; *N. J. Kasdin;* [3]; *W. B. Sparks;* [4]; *M. C. Turnbull;* [5]; *M. J. Kuchner;* [6]; *A. Roberge;* [6]; *S. Domagal-Goldman;* [6]; *S. Shaklan;* [7]; *M. Thomson;* [7]; *D. Lisman;* [7]; *S. Martin;* [7]; *E. Cady;* [7]; *D. Webb;* [7];

1. Massachusetts Institute of Technology, Cambridge, MA, United States.
2. University of Colorado, Boulder, CO, United States.
3. Princeton University, Princeton, NJ, United States.
4. STScI, Baltimore, MD, United States.
5. Global Science Institute, Antigo, WI, United States.
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Abstract (2,250 Maximum Characters): "Exo-S" is NASA's first directed community study of a starshade and telescope system for space-based discovery and characterization of exoplanets by direct imaging. Under a cost cap of $1B, Exo-S will use a modestly sized starshade (also known as an "external occulter") and a modest aperture space telescope for high contrast observations of exoplanetary systems. The Exo-S will obtain spectra of a subset of its newly discovered exoplanets as well as already known Jupiter-mass exoplanets. Exo-S will be capable of reaching down to the discovery of Earth-size planets in the habitable zones of twenty sun-like stars, with a favorable few accessible for spectral characterization. We present highlights of the science goals, the mission design, and technology milestones already reached. At the study conclusion in 2015, NASA will evaluate the Exo-S concept for potential development at the end of this decade.

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Exo-C: A probe-scale space mission to directly image and spectroscopically characterize exoplanetary systems using an internal coronagraph

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Abstract (2,250 Maximum Characters): "Exo-C" is NASA's first community study of a modest aperture space telescope designed for high contrast observations of exoplanetary systems. The mission will be capable of taking optical spectra of nearby exoplanets in reflected light, searching for previously undetected planets, and imaging structure in a large sample of circumstellar disks. We present the mission/payload design and highlight steps to reduce mission cost/risk relative to previous mission concepts. At the study conclusion in 2015, NASA will evaluate it for potential development at the end of this decade.