Keck Science Meeting
2017

Abstracts

September 14 - 15, 2017
Santa Cruz, CA

Agenda

Thursday, September 14, 2017

08:00 | Breakfast
08:50 | Ryan Foley: Welcome and Introductions

Session I | Session Chair: Tom Prince

09:00 | Hilton Lewis: State of Keck Observatory
09:30 | Erik Petigura: The California-Kepler Survey
09:45 | Marusa Bradac: Reionisation and First Galaxies with Keck
10:00 | Kelly Kosmo O'Neil: Improving Estimates of Orbital Parameters for Incomplete Orbits with a New Approach to Priors
10:15 | Emma Ryan-Weber: Galaxies and Intergalactic Carbon at Redshifts 4 to 6
10:30 | Break

Session II | Session Chair: Jean Brodie

10:50 | Pieter van Dokkum: Properties of Ultra Diffuse Galaxies
11:05 | Rachel Smith: A Survey of Protoplanetary Carbon in Young Stellar Systems Using Keck-NIRSPEC
11:20 | Nicha Leethochawalit: On the Evolution of stellar MZR: Cl0024+1654 Stellar Metallicities
11:35 | Charles Kilpatrick: Uncovering the Progenitors of Core-collapse Supernovae with Keck Adaptive Optics and High-Resolution Spectroscopy
11:50 | Jeff Cooke: The first $z > 2$ supernova spectra in outburst: A first look at their far-UV, their classification, and a puzzle
12:05 | Lunch

Session III | Session Chair: Bob Kirshner

13:15 | Anne Kinney: Update from Time Domain Astronomy Workshop
13:30 | Marta Bryan: Constraining the Origin of Young Planetary-Mass Companions Using Planetary Spin
13:45 | Andrey Vayner: Quasar hosts Unveiled by high Angular Resolution Techniques (QUART)
14:00 | Grant Hill: Modeling the Colliding Wind Spectra of WR 113
14:15 | Ann Merchant Boesgaard: Light Element Abundances in the Hyades Cluster
14:30 | "Poster Pop" (Poster Presentations)
15:00 | Break/Posters

Session IV | Session Chair: Mike Bolte

15:45 | Mark Chun: `imaka: Exploring wide field ground-layer adaptive optics on Maunakea
16:00 | Leo Alcorn: The Kinematics of Star-Forming Galaxies at $z \sim 2$
16:15 | Marie Wingyee Lau: Quasars Probing Quasars: the circumgalactic medium surrounding $z \sim 2$ quasars
16:30 | Ben Mazin: KRAKENS: A Microwave Kinetic Inductance Detector based IFS for Keck I
16:45 | Tiffany Meshkat: Occurrence of giant planets around stars with dusty debris disks
17:00 | Nikki Nielsen: The MgII Circumgalactic Medium in Group Environments

Friday, September 15, 2017

08:00 | Breakfast

Session V | Session Chair: Karl Glazebrook

09:00 | Michitoshi Yoshida: Director's Report (Subaru Telescope)
09:30 | Brian Hayden: See Change: The Supernova Cosmology Project High-z Cluster Supernova Survey
09:45 | Evan Sinukoff: Exploring the Compositional Diversity of Small Exoplanets from K2
10:00 | Judy Cohen: Keck Helping Euclid, a Status Report for the C3R2 Project
10:15 | Matthew Hosek: The Initial Mass Function of the Arches Cluster
10:30 | Break

Session VI | Session Chair: Judy Cohen

10:50 | Masato Onodera: ISM properties of star-forming galaxies at z~3.3 from MOSFIRE spectroscopy
11:05 | David Bennett: Measuring the Cold Exoplanet Mass Function with Keck AO
11:20 | Asher Wasserman: Measuring Dark Matter in Massive Galaxies
11:35 | Thayne Currie: Multi-Wavelength Characterization of Keck-Discovered Directly-Imaged Exoplanets
11:50 | Alex Krolewski: CLAMATO: Mapping the z~2 universe with 3D Lyman-alpha forest tomography
12:05 | Lunch

Session VII | Session Chair: Marusa Bradac

13:15 | Jean Brodie: Keck White Papers -- Introduction
13:21 | Jessica Lu: Enhancing Multi-Object Spectroscopy with Ground-Layer Adaptive Optics
13:33 | Dimitri Mawet: NIRC2 Upgrade
13:45 | James Larkin: New AO IFS design
13:57 | Claire Max: UCO White Papers
14:00 | Don Neill: KCWI Update

14:10 | Ji Wang: Detecting Methane In HR 8799 c with High Dispersion Spectroscopy aided by Adaptive Optics
14:25 | Adam Tomczak: The Galaxy Stellar Mass Function: Glimpsing the Effect of Local Environment
14:40 | David Fisher: DYNAMO: An up-close view of turbulent disk galaxies
14:55 | Break

Session VIII | Session Chair: Claire Max

15:15 | Anna Ciurlo: Gas Dynamics at the Galactic Center
15:30 | Stephanie Pointon: The Impact of the Group Environment on the OVI Circumgalactic Medium
15:45 | Dimitri Mawet: Keck Planet Imager and Characterizer: status update
16:00 | Gregory Walth: Using Cosmic Telescopes to Study the Nebular Emission of Gravitationally Lensed Dusty, Star-Forming Galaxies with Keck
16:15 | Hassen Yesuf: Studying Galactic Winds, Stellar populations, and Gas Metallicities with Deep Keck Spectroscopy
16:30 | Devin Chu: Investigating the binarity of the short period star S0-2 in orbit around the Galactic center supermassive black hole
16:45 | Calen Henderson: Using AO Follow-up to Characterize Microlensing Exoplanets

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Science Organizing Committee Chair:
Ryan Foley, Asst. Professor, Department of Astronomy and Astrophysics at UC Santa Cruz

Science Organizing Committee:
Marusa Bradac, Assoc. Professor, Department of Physics, UC Davis
Tom Greene, Astrophysicist, NASA Ames Center for Exoplanet Studies
Brad Holden, Academic Researcher at UC Observatories / Lick Observatory
Andrew Howard, Professor, Department of Astronomy, Caltech
Anne Kinney, Chief Scientist, W.M. Keck Observatory
Evan Kirby, Asst. Professor, Department of Astronomy, Caltech
Alice Shapley, Professor, Department of Physics and Astronomy, UCLA
Shelley Wright, Asst. Professor, Department of Physics, UC San Diego

Abstracts

Thursday, September 14th, 2017

Session I (9:00 – 10:30 am) — *Session Chair: Tom Prince*

Hilton Lewis | W.M. Keck Observatory

State of Keck Observatory

Erik Petigura | Caltech

The California-Kepler Survey

While Kepler has revealed over 4000 planets, key challenges to understanding their demographics are the often large uncertainties in host star properties. The California-Kepler Survey (CKS) is a large spectroscopic survey with the aim of bringing the properties of Kepler host stars into sharper focus. Using Keck/HIRES, we obtained high resolution (R=50,000), high SNR spectra of 1305 Kepler stars hosting over 2000 planet candidates. These spectra enable precise measurements of planet sizes, host star metallicity, and other quantities. I will give an overview of this survey and highlight key results, including the discovery of a gap in the size distribution of planets between Earth and Neptune size. This bimodality is likely the result of photo-evaporative sculpting.

Marusa Bradac | UC Davis

Reionisation and First Galaxies with Keck

In the recent years HST observations of blank fields enabled us to detect galaxies as far as z~11. However, very little is known about those galaxies, and they are mostly the most luminous representatives. Clusters of galaxies, when used as cosmic telescopes, can greatly simplify the task of studying and finding normal galaxies at high redshifts. In particular, they allow us to see galaxies that are likely beacons of the epoch of reionization, which marked the end of the so-called ”Dark Ages" and signified the transformation of the universe from opaque to transparent. Several large surveys have recently been executed (CLASH, HFF, Relics) and several are planned with KECK with the main goal of identifying and studying star formation of galaxies at z>~6. I will present results from these surveys and what can be learned from them and show successful detections of galaxies at z~7 and beyond with MOSFIRE and DEIMOS.

Kelly Kosmo O'Neil | UCLA

Improving Estimates of Orbital Parameters for Incomplete Orbits with a New Approach to Priors

Over twenty years of monitoring stellar orbits at the Galactic center has provided an unprecedented opportunity to study the physics and astrophysics of the supermassive black hole (SMBH) at the center of the Milky Way Galaxy. To constrain the mass of and distance to the black hole, and to evaluate its gravitational influence on orbiting bodies in order to test General Relativity, Bayesian inference is often used to infer black hole and stellar orbital parameters from astrometric and radial velocity measurements of stars orbiting the central SMBH. In prior-dominated regions, however, statistical effects can obscure actual physical effects such as those from General Relativity. Most of the short-period stars in the Galactic center have periods much longer than our twenty year time baseline of observations, resulting in incomplete orbital phase coverage -- potentially exacerbating prior influence, thereby biasing fitted parameters and producing inaccurate confidence intervals. We thus propose a new solution to reduce biases and to ensure acceptable coverage of the resulting confidence intervals for orbits where data are not rigorously constraining, such as in instances of low phase coverage or when observations do not cover periapse. The explored solution assumes a prior that is based on observables rather than on the inferred model parameters, as is the current standard method of orbit fitting. We apply this methodology to the Galactic center as well as to the HR 8799 planetary system, as the proposed method will not only improve orbital estimates of stars orbiting the central SMBH, but can also be extended to other orbiting bodies with low phase coverage such as visual binaries and exoplanets. Of the cases tested, in regions of prior-dominance, priors based on uniformity in the observables reduce biases in the fitted parameters and ensure that the errors are not under-estimated, as is the case with standard uniform priors.

Emma Ryan-Weber | Swinburne University of Technology

Galaxies and Intergalactic Carbon at Redshifts 4 to 6

The high redshift Intergalactic medium - including its metal content - sets the initial conditions from which modern galaxies form and evolve. I will present work (including Keck, Subaru and VLT observations) on the relationship between galaxies and carbon seen in absorption towards redshift 6 quasars. I will address: What causes the sudden drop in the mass density of triply ionised carbon at redshift 5? Can we identify the galaxies responsible for these metals?

Pieter van Dokkum | Yale University

Properties of Ultra Diffuse Galaxies

In 2015 we discovered a substantial population of previously-unknown galaxies in the Coma cluster, using the Dragonfly Telephoto Array. These "ultra diffuse galaxies" (UDGs) have the stellar masses and luminosities of dwarf galaxies, but the sizes of ~L* galaxies (with half-light radii of up to ~5 kpc). I will discuss ongoing efforts and plans to characterize these galaxies with extremely deep DEIMOS, LRIS, and KCWI spectroscopy. This includes ultra-deep (>30 hr) high spectral resolution observations to measure their stellar kinematics, and efforts to characterize their (surprisingly rich) globular cluster systems.

Rachel Smith | Appalachian State University

A Survey of Protoplanetary Carbon in Young Stellar Systems Using Keck-NIRSPEC

High-resolution near-IR absorption spectroscopy of the rovibrational transitions of carbon monoxide (CO) gas toward young stellar objects (YSOs) enables precise evaluation of carbon and oxygen isotopes in these systems, providing valuable insights into protoplanetary and prebiotic pathways. Comparisons can also be made between solar system materials and young stellar gas, furthering our understanding of phenomena relevant to the early solar nebula. Massive YSOs are particularly valuable for evaluating protoplanetary and prebiotic carbon chemistry, since they are bright (~ 10^3 to 10^5 solar-luminosities) and enable observations over a significant range of Galactocentric radii (R_GC). Further, observations of CO in the gas-phase can be compared to other carbon-based reservoirs along the same lines of sight, permitting useful evaluation of carbon chemistry along a pencil-beam in multiple solid- and gas-phase reservoirs. Here we present results from our carbon isotope (12C/13C) survey of massive YSOs at R_GC from ~ 0.01 to 10 kiloparsecs (kpc), observed with Keck-NIRSPEC. Used in high-resolution mode (3-pixel slit, R~25,000), NIRSPEC is an ideal tool for exploring carbon chemistry of YSOs that rely on precise gas-phase CO isotopologue column densities. Our survey includes 21 massive YSOs, 5 low-mass YSOs, and 1 background star. We obtained M-band (υ=1−0, 4.7 μm) rovibrational spectra to capture mid- to low-J lines in absorption for 13C16O, 12C18O and 12C17O isotopologues, and K-band (υ=2−0, 2.3 μm) spectra for optically thin 12C16O lines. Equivalent widths were derived with polynomial/Gaussian fits. Doppler broadening, integrated gas temperatures, and total isotopologue column densities were determined using curve-of-growth and rotational analyses. Thus far, derived CO Doppler broadening values range from 3 to 9 km/s. Rotational analyses for three targets reveal cold (T ~ 10 to 20 K) and warm (T ~100 to 200 K) in the CO gas, while only cold regimes (T ~ 30 to 40 K) were observed toward embedded massive cores. Ratios of 12C/13C derived from CO gas do not significantly resemble those from solid [12CO2]/[13CO2], suggesting alternative/more complex processing of carbon rather than simple inheritance of CO2 from a CO reservoir. Unlike the heterogeneity found in gas-phase [12CO]/[13CO] toward low-mass YSOs at R_GC ~ 8 kpc (surveyed with VLT-CRIRES, Smith et al. 2015, ApJ), we find that cold gas-phase [12CO]/[13CO] in the massive YSOs seem to follow the Galactic metallicity trend, suggesting some alternative processing pathways between low- and high-mass YSOs. Yet, similarities are found in high- and low-mass YSOs: targets with two-temperature regimes reveal higher [12CO]/[13CO] from warm versus cold gas, and CO gas-phase reservoirs may be similarly affected by CO ice in both low- and high-mass YSOs. This project lends itself extremely well for testing the slated 2018 NIRSPEC upgrades: the significantly increased spectral resolution (up to R~ 60,000) will vastly improve the derivation of accurate line widths (and thus column densities), and the nearly 50% increase in lines per order and new M-band guiding will improve efficiency. Further, the planned lower read noise and lack of non-random pattern noise will improve sensitivity for faint sources, particularly important for deeply embedded K-band observations.

Nicha Leethochawalit | Caltech

On the Evolution of stellar MZR: Cl0024+1654 Stellar Metallicities

We present the stellar mass–stellar metallicity relationship (MZR) in the Cl0024+1654 galaxy cluster at z = 0.4 using full spectrum stellar population synthesis modeling of individual quiescent galaxies. The lower limit of our stellar mass range is $M_* = 10^{9.2}\ M_\odot$, the lowest galaxy mass at which stellar metallicity has been measured beyond the local universe. Even at the lowest masses, where we expect the evolution of the stellar MZR with redshift to be the greatest, we do not detect such an evolution over the past 4 Gyr, in mild tension with the predictions of some analytic models and hydrodynamical simulations. However, we detect an evolution of the stellar MZR with the SSP-equivalent age of galaxies, i.e., their formation redshifts. This behavior is consistent with stars forming out of gas that also has an MZR with a normalization that decreases with redshift. Lastly, we find that over the observed mass range, the MZR can be described by a linear function with a shallow slope ($[Fe/H] \propto M_*^{0.17\pm0.03}$). The slope suggests that galaxy feedback, in terms of mass-loading factor, might be mass-independent over the observed mass and redshift range.

Charles Kilpatrick | UC Santa Cruz

Uncovering the Progenitors of Core-collapse Supernovae with Keck Adaptive Optics and High-Resolution Spectroscopy

Any explosive transient can become extremely valuable in the rare cases when a massive progenitor star is detected in pre-explosion imaging. In these cases, precise estimates of the ejecta mass, abundances, and kinetic energy derived from observation of the explosive transient are crucial since they can be compared with the estimated mass and type of star that exploded. However, the number of nearby explosive transients with deep pre-explosion imaging is small, and each new event must be optimally and rapidly exploited in order to obtain much information as possible connecting the transient event and progenitor star. Keck adaptive optics imaging has enabled us to precisely identify the locations of explosive transients and associate these systems with their pre-explosion counterparts. Spectroscopy further establishes a connection to pre-explosion counterparts by revealing signatures of massive star winds and the mass-loss history of the progenitor system. I will discuss the critical role that Keck plays in connecting explosive transient systems to their pre-explosion counterparts and the observational challenges involved in these studies. I will focus on recent examples, especially the stripped-envelope SNe 2016gkg and 2017ein, which were observed with Keck/NIRC2 and OSIRIS in conjunction with adaptive optics to precisely constrain their locations and associate these objects pre-explosion sources in HST imaging. Finally, I will discuss the follow-up of explosive transients with pre-explosion counterparts, with a focus on using Keck high-resolution spectroscopy to constrain the mass-loss histories of massive stars.

Jeff Cooke | Swinburne University of Technology

The first z > 2 supernova spectra in outburst: A first look at their far-UV, their classification, and a puzzle

I will present the first spectra of high redshift (z > 2) superluminous supernovae (SLSNe) in outburst. We detect the supernovae using the Dark Energy Survey (DES) SN survey, the Hyper SuprimeCam Subaru Strategic Program (HSC-SSP), and the Survey Using DECam for Superluminous Supernovae (SUDSS). These surveys have been operating for ~3 years and have finally achieved sufficient depth and temporal baseline to detect a sufficient number of z ~ 2 - 6 supernovae to enable spectroscopy near peak using classically scheduled Keck time. I will present deep spectroscopy of 5 SLSNe (with more spectra planned this semester) and I will briefly discuss one event that has proven to be enigmatic. The spectra are dense with atomic transitions and signatures that are proving very powerful in discriminating physical models and explosion mechanisms. SLSNe can be detected to z ~ 20 with JWST, further than any galaxy, providing essentially our only beacons at these early epochs. SLSNe have great utility in a broad range of areas, including galaxy formation and evolution, reionization, high redshift ISM, CGM, and IGM studies, the cosmic chemical enrichment, and Population III star studies. The LRIS rest-frame far-UV data is essential to understand and classify z ~ 2 - 6 events in the optical and at z > 6 in the near-IR. These data provide a much-needed first sample, as the number of z > 2 SLSN candidates currently exceeds the number at low redshift, and the number with spectra are expected to exceed that at low redshift shortly after the launch of JWST.

Session III (12:05 – 2:30 pm) — *Session Chair: Bob Kirshner*

Anne Kinney | W.M. Keck Observatory

Update from Time Domain Astronomy Workshop

Marta Bryan | Caltech

Constraining the Origin of Young Planetary-Mass Companions Using Planetary Spin

Over the past decade, direct imaging searches for young gas giant planets have revealed a new population of companions with orbital separations of over 100 AU and masses near or at the deuterium burning limit. Thus far, 18 wide-separation planetary-mass companions have been confirmed, most of which are less than 10 Myr old. These wide- separation planetary-mass companions pose significant challenges to all three possible formation mechanisms, including core accretion, disk instability, and turbulent fragmentation. By obtaining high-resolution K-band spectra of a sample of directly imaged wide-separation planetary mass companions using NIRSPEC and NIRSPEC-AO at Keck, we can directly test these three competing formation mechanisms from two different angles. First we use these spectra to measure rotation rates of these planetary-mass companions and compare them to a sample of rotation rates that we measured for planetary-mass brown dwarfs. In addition, we obtain the first measurements of the atmospheric C/O ratios of these companions, and compare these ratios to those of their host stars and a sample of planetary-mass brown dwarfs from the same star forming region.

Andrey Vayner | W.M. Keck Observatory

Quasar hosts Unveiled by high Angular Resolution Techniques (QUART)

We have been conducting a new multi-wavelength survey of distant (1.3 < z < 2.6) luminous quasar host galaxies using Keck laser-guide star adaptive optics (LGS-AO) and OSIRIS. Studying distant host galaxies of quasars is essential for understanding the role of active galactic nuclei (AGN) feedback and its potential impacts on the interstellar medium (ISM) and capability of regulating the growth of both galaxy and supermassive black hole (SMBH). The combination of LGS-AO and OSIRIS affords the necessary spatial resolution and contrast to disentangle the bright quasar emission from that of its faint galaxy. We are able to resolve the nebular emission lines; Hβ, [OIII], [NII], Hα and [SII] at sub-kiloparsec resolution to study the distribution, kinematics and dynamics of the warm-ionized interstellar medium (ISM) in the host galaxy. One of the primary survey goals is to study outflows in ionized emission, and relate their spatial extent and energetics to the star forming properties of the host galaxy. In approximately half of our sample we detect clear extended outflows on a 1-12 kpc scale, over regions where there is no significant evidence of recent star formation. In one particular source, 3C 298 (z=1.439), the amalgamation of OSIRIS and ALMA data allows the simultaneous study of the effects of AGN negative feedback on multiple phases of the ISM. We show that powerful outflows exist in both ionized and molecular state in 3C 298 with no evidence of concurrent star formation with a quenching time of molecular gas on several Myrs. This is some of the strongest evidence to support quasar negative feedback directly halting star formation in a galaxy at the peak epoch of SMBH and galaxy growth. We will address the entire survey status and discuss the exciting capabilities that KCWI will bring to our ongoing multi-wavelength program.

Grant Hill | W.M. Keck Observatory

Modeling the Colliding Wind Spectra of WR 113

Striking profile variations of the CIII 5696 emission line are visible amongst the high signal-to-noise ratio, moderate resolution spectra of the 29.7dWC8d+O8-9IV binary CV Ser (WR 113) presented here. Using significantly revised code, we have modelled these variations assuming the emission originates from the undisturbed WR star wind and a colliding wind shock region which partially wraps around the O star. This modelling provides measurements of crucial parameters such as the orbital inclination and thus, together with the RV orbits, the stellar masses. We find good agreement with expectations based on theoretical studies and hydrodynamical modelling of colliding wind systems. Moreover, it raises the exciting prospect of providing a reliable method to learn more about WR stellar masses and winds, and for studying the physics of colliding winds in massive stars.

Ann Merchant Boesgaard | IfA, University of Hawaii

Light Element Abundance in the Hyades Cluster

Light Element Abundances in the Hyades Cluster (title) -- The abundances of Li, Be, and B in stars provide almost the only direct observational information about the interiors of stars. These three elements are destroyed inside stars at increasingly hotter temperatures: 2.5×10^6, 3.5×10^6 and 5×10^6 K for Li, Be, B respectively. Consequently, these elements survive to increasingly greater depths in a star and their surface abundances act as a report on the depth and thoroughness of mixing in the star. Dramatic deficiencies of Li in the mid-F dwarf stars of the Hyades cluster were discovered by Boesgaard and Tripicco in 1986. Using high-resolution, high signal-to-noise spectra from the Keck 10-m telescope, Boesgaard and King discovered the corresponding, but smaller, deficiencies in Be in the same narrow temperature region in the Hyades. Additional recent spectra of both Li and Be from HIRES and a new temperature scale from Hipparcos data have verified and expanded these results. We have now added B abundances with spectra from HST. We have Li abundances (or upper limits) for 79 Hyades dwarfs, Be for 34 stars, and B in five stars. We find evidence for a small dip in the B abundance across the Li-Be dip. Theoretical models that match the element depletions indicate that spin-down from initial high rotation rates produces the extra mixing needed for atoms of these rare, light to reach depths where they are destroyed and by the amounts predicted for each element.

Mark Chun | IfA, University of Hawaii

`imaka: Exploring wide field ground-layer adaptive optics on Maunakea

Adaptive optics systems are now commonplace at all major astronomical observatories and the next generation of systems seek to improve the field of view or the level of correction. One approach, ground-layer adaptive optics (GLAO), trades the level of correction for the size of the corrected field of view. Measurements of the origin and nature of the optical turbulence above Maunakea suggest that it is an ideal site for GLAO as the residual uncorrected high-altitude turbulence is weak and the ground-layer turbulence is highly confined to a few tens of meters above the site. Together these suggest GLAO on Maunakea can reach the free-atmosphere seeing (⅓”) over fields of view of tens of arcminute in size. To quantify the scientific gains and to develop the experience using GLAO on Maunakea we have deployed a GLAO testbed, `imaka, on the University of Hawaii 2.2-meter telescope. `imaka is now commissioned and demonstrating resolution, sensitivity, and astrometric gains from a GLAO system with guide stars spread over fields of view up to 16 arcminutes. We present results from our initial on-sky experiments along with predictions from our overall system error budget and simulations. Importantly the `imaka experience, simulations, and results are feeding into the studies of future GLAO systems on Keck and Subaru.

Leo Alcorn | Texas A&M University

The Kinematics of Star-Forming Galaxies at z~2

We perform a kinematic and morphological analysis of 42 star-forming galaxies at z~2 in the COSMOS legacy field using near-infrared spectroscopy from Keck/MOSFIRE and F160W imaging from CANDELS as part of the ZFIRE survey. Our sample consists of galaxies from the over-dense region at z=2.095 in COSMOS as well as field objects from 2.0 < z < 2.5. We measure H-alpha rotational velocities and gas velocity dispersions in an innovative method, which compares directly to simulated 3D data-cubes. We examine the role of regular and irregular morphology in the stellar mass kinematic scaling relations, deriving the kinematic measurement $S_{0.5}$, and find no significant offset between morphological populations. The scatter for irregulars (~0.179 dex) is larger than for regulars (~0.09 dex). We determine a best-fit v/σ_g for the total sample, showing an increasing level of rotation dominance with increasing M_{ast}, and a high level of scatter, particularly for irregular galaxies. We estimate the specific angular momenta of these galaxies, and find a lower amount of angular momentum at lower masses than predicted if the angular momentum of the disk preserved the angular momentum of the halo. Our findings provide further evidence for kinematic downsizing, showing the increasing sensitivity of low-mass galaxies to the processes that strip angular momentum from the disk.

Marie Wingyee Lau | UC Santa Cruz

Quasars Probing Quasars: the circumgalactic medium surrounding z ~ 2 quasars

I characterize the physical properties of the cool T ~ 10^4 K circumgalactic medium (CGM) surrounding z ~ 2 quasar host galaxies, which are predicted to evolve into present-day massive ellipticals. Using a statistical sample of 112 background quasar spectra passing within 300 kpc transverse distance from foreground quasars with precise systemic redshift measurements, I examine the kinematics. The systemic redshifts are measured with emission lines with precision <300 km/s and average offsets from the systemic <|100 km/s|. I stack the background quasar spectra at the foreground quasar's systemic redshift to study the mean absorption in CII, CIV, and MgII. I find that the mean absorptions exhibit large velocity widths σ_v > 300 km/s. The observed widths are consistent with gas in gravitational motion and Hubble flow, and galactic-scale outflows are not required to explain the large widths. I find that the mean absorptions are asymmetric about the systemic redshift. The centroids exhibit small redshift relative to the systemic delta v = +200 km/s, with large intrinsic scatter in the centroid velocities of the individual absorption systems. I show that the observed offsets may be produced if (i) the ionizing radiation from the foreground quasars is anisotropic or intermittent and (ii) the gas is not flowing into the galaxy. Then, using a statistical sample of 14 quasar pairs and background spectra of high dispersion and high signal-to-noise ratio, I examine the chemical enrichment, ionization states, surface density profiles, density and size of the absorbers. The CGM is significantly enriched, even beyond the virial radius, with a median metallicity [M/H] = −0.6. The alpha/Fe abundance ratio is enhanced, suggesting that halo gas is primarily enriched by core-collapse supernovae. The projected cool gas mass within the virial radius is estimated to be $1.9*10^{11}$ M_sun (R_{perp} ~160 kpc)^2, accounting for 1/3 of the baryonic budget of the galaxy halo. The ionization state of CGM gas increases with projected distance from the foreground quasars, contrary to expectation if the quasar dominates the ionizing radiation flux. However, I also found peculiarities not exhibited in the CGM of other galaxy populations. In one absorption system, I may be detecting unresolved fluorescent Lyman-alpha emission, and another system shows strong NV lines. Taken together, these anomalies suggest that transverse sightlines are - at least in some cases - possibly illuminated. I also discovered a peculiar case where detection of the CII fine-structure line implies an electron density >100 cm^{-3} and sub-parsec-scale gas clumps.

Ben Mazin | UC Santa Barbara

KRAKENS: A Microwave Kinetic Inductance Detector based IFS for Keck I

Microwave Kinetic Inductance Detectors, or MKIDS, are superconducting detector arrays that can measure the energy and arrival time of individual optical and near-infrared photons without false counts. Their integration into astronomical instruments over the last five years is arguably the largest detector upgrade optical to near-IR Astronomy has seen since the switch from photographic plates to CCDs and Infrared arrays. In this proposal we seek to take the MKID technology, which we have demonstrated on the Palomar and Lick Telescopes and soon on the Subaru Telescope and a NASA Stratospheric Balloon, out of the realm of private instruments usable only by experts. Our goal is to transform MKIDs into a facility class instrument for the Keck I Telescope usable by a significant part of the broad astronomical community. This new instrument, the Keck Radiometer Array using KID ENergy Sensors (KRAKENS), will be a 30 kpix integral field spectrograph (IFS) with a 45"x45" field of view, extraordinarily wide wavelength coverage from 380-1350 nm, and a spectral resolution R>20 at 400 nm. Future add on modules will enable polarimetry and higher spectral resolution. KRAKENS will be built using the same style MKID arrays, cryostat, and identical readout electronics to those used in the installed 10 kpix DARKNESS instrument at Palomar and 20 kpix MEC instrument at Subaru, significantly reducing the technical risk. KRAKENS was submitted as a MRI proposal in January 2017 and received relatively strong scores, but was ultimately unsuccessful in its first attempt. We plan a resubmission in the next cycle.

Tiffany Meshkat | Caltech

Occurrence of giant planets around stars with dusty debris disks

Debris disks may be the signposts of recent planet formation. The dust, which is generated in collisional cascades of asteroids and comets, is enhanced by the gravitational stirring of gas giant planets. Thus bright debris disk systems are natural targets for imaging searches for planets, as it indicates that the host star likely possesses some kind of planetary system. In this work, we describe a joint high contrast imaging survey for planetary mass companions at Keck and VLT of the last significant sample of debris disks identified by the Spitzer Space Telescope. No new substellar companions were discovered in our survey of Spitzer-selected targets. We combine these observations with from three published surveys, to put constraints on the frequency of planets around debris disk stars in the largest sample to date. We also obtained published data on stars which do not show infrared excesses for a control sample. We assume a double power law distribution of the form $f(m,a) = Cm^{\alpha} a^{\beta}$ for this population of companions. We find that the frequency of giant planets with masses 5-20 M_{Jup} and separations 10-1000 AU around stars with debris disks is 6.2% (68% confidence interval 3.6-9.7%), compared to 0.68% (68% confidence interval 0.2-1.7%) for the control sample of stars without disks. For the first time, we show that the occurrence of young giant planets around stars with debris disks is higher than those without debris disks at the 88% confidence level, tentatively suggesting that these distributions are distinct.

Nikki Nielsen | Swinburne University of Technology

The MgII Circumgalactic Medium in Group Environments

The flow of gas through galaxies is key to understanding the observed global properties of galaxies and their evolution. Extensive work has gone into characterizing this baryon cycle gas as it moves through the circumgalactic medium (CGM) of isolated galaxies, where MgII absorption kinematics and equivalent widths depend strongly on the star formation rate and MgII is commonly associated with outflows and recycled accretion. However, little work has been done to characterize the CGM in group environments, where other processes such as tidal stripping due to galaxy interactions may contribute to the observed CGM properties. The large radius of the CGM is also useful for investigating the very first processes that take place in an interaction even when the visible portions of galaxies may not be disturbed. Using 19 MgII absorbers associated with group environments (2-5 galaxies), we compare the group CGM kinematics and absorption properties from HIRES/Keck and UVES/VLT spectra to those of the isolated CGM to quantify the effect that environment has on the CGM.

Friday, September 15th, 2017

Session V (9:00 – 10:30 am) — *Session Chair: Karl Glazebrook*

Michitoshi Yoshida | Subaru Telescope

Director's Report

Brian Hayden | UC Berkeley

See Change: The Supernova Cosmology Project High-z Cluster Supernova Survey

The "See Change" program was a large HST program spanning cycles 22 (GO-13677) and 23 (GO-14327), using 174 orbits to discover and characterize ~30 type Ia supernovae at z>1. The primary scientific goal of See Change is to improve our knowledge of the expansion history of the universe through distance measurements of high-z type Ia supernovae, and calibration of the SZ-mass scaling relation using weak-lensing in the most massive, highest redshift clusters known to date. The Keck telescope formed the backbone of our redshift survey program for our northern cluster targets. Our goal was to obtain redshifts for transients in our program, especially type Ia SNe, and increase the generally low number of confirmed cluster members in these high-redshift environments. I'll discuss the supernova sample and ongoing blinded cosmology analysis, as well as the specific challenges of the ground-based program in the low signal-to-noise regime.

Evan Sinukoff | IfA, University of Hawaii

Exploring the Compositional Diversity of Small Exoplanets from K2

We present results from the first year of the NASA Keck Key Project to measure the masses of small planets from the K2 Mission using Keck/HIRES. This project explores the compositional diversity of planets between the size of Earth and Neptune and identifies suitable targets for atmospheric study by JWST. So far, we have measured the masses and densities of more than 20 sub-Neptune-size planets, significantly expanding on the mass/radius measurements from Kepler. Our measurements help to map out the transition from rocky to gas-dominated planets with higher fidelity and probe the dependence of planet composition on planet radius, incident flux, host star properties, and system architecture, connecting bulk planet composition with planet formation and evolution.

Judy Cohen | Caltech

Keck Helping Euclid, a Status Report for the C3R2 Project

The progress of the C3R2 project (the Complete Calibration of the Color-Redshift Relation) for the Euclid dark energy mission (an ESA project with NASA participation) will be discussed. At this time we have close to 4000 new redshifts of faint field galaxies in well-studied deep fields. Most are close to the limiting depth of Euclid, and have been selected through a machine learning technique to be the most useful at enhancing the accuracy of photometric redshifts, to improve the calibration which will be used for billions of galaxies to be imaged by Euclid with the on-board optical and near-IR imagers.

Matthew Hosek | IfA, University of Hawaii

The Initial Mass Function of the Arches Cluster

At a projected distance of just ~26 pc from Sgr A*, the Arches cluster allows us to examine the impact of the extreme Galactic Center environment on the Initial Mass Function (IMF). However, measuring the IMF of the Arches is challenging due to the large and highly variable extinction along the line of sight, which makes it difficult to identify cluster members. We use 10 years of high-precision astrometric and photometric measurements of the Arches cluster using Keck NIRC2 and the Hubble Space Telescope the measure the proper motions of stars down to 2 M_sun out to the outskirts of the cluster (3 pc). These proper motions allow us to calculate a cluster membership probability for each star and obtain a much cleaner cluster sample than is possible through photometry alone. We also obtain Keck OSIRIS K-band spectroscopy of a sample of cluster members, which provide constraints on the age of the cluster. We forward model these observations in a Bayesian analysis framework to simultaneously constrain the cluster IMF, age, distance, and extinction. Ultimately, we will compare the IMF of the Arches to similar clusters in the Galactic disk and quantify the effect of the GC environment on the star formation process.

Masato Onodera | Subaru Telescope

ISM properties of star-forming galaxies at z~3.3 from MOSFIRE spectroscopy

We will present results from our near-IR spectroscopic campaigns with Keck/MOSFIRE for star-forming galaxies at 3<z<3.7 for which most of the observing nights were awarded through the Subaru-Keck time exchange program. By using MOSFIRE H and K band spectra as well as ancillary photometric data, we studied gas-phase oxygen abundance, electron density, and ionization parameters of ionized gas in these galaxies selected via either UV, photo-z, or narrow-band excess. We found these three selection methods do not show any differences in the physical conditions of ionized interstellar medium (ISM), while on average the ISM physical conditions are significantly different from local typical star-forming galaxies, namely, ~0.7 dex lower gas-phase metallicities, higher ionization parameters, and ~10 times higher electron densities. Compared with well studied z~2 mass--metallicity relation (MZR), evolution seems milder up to ~0.3 dex in MZR depending on which metallicity calibration is used. We also found less important role of star formation rate (SFR) in MZR in contrast to that in the local Universe. Comparison of MZR evolution with a simple model of star formation suggests a weak evolution of star formation efficiency.

David Bennett | NASA Goddard Space Flight Center

Measuring the Cold Exoplanet Mass Function with Keck AO

In order to derive the exoplanet mass function for cold planets discovered by microlensing, it is necessary to combine the result of light curve modeling with at least two lens mass-distance relations. For most planetary events, finite source effects allow the source radius crossing time to be measured, and this yields the angular Einstein radius. This yields a mass distance relation that can be combined with lens flux measurements from Keck adaptive optics imaging to constrain or measure the masses of cold exoplanet host stars. The planet masses are determined directly from the host star masses because the planetary microlensing light curves reveal the planet:star mass ratio. Our high angular resolution follow-up program has observed 25 planetary systems, leading to 19 published papers, with papers on an additional 5 systems to be submitted in the next month or two. These results will then be added to statistical analyses of planetary microlensing signals to determine the cold exoplanet mass function as a function of host star mass and distance. This result will be independent of the similar analysis planned using the Spitzer exoplanet microlensing measurements, but will be able to use a larger exoplanet sample. Are talk will focus on the most recent results from our program.

Asher Wasserman | UC Santa Cruz

Measuring Dark Matter in Massive Galaxies

While Lambda CDM has had numerous successes in describing the large scale structure of the universe, there remain challenges in reconciling differences between theory and observation on the scale of galaxies. In particular I focus on the cusp-core problem, which refers to variations of the inner density slope of dark matter halos that have been observed across a wide range of mass scales. Here I present new dynamical models of the massive slow-rotating elliptical galaxy, NGC 1407. The depth of kinematic data from Keck/DEIMOS on both the stars and globular clusters enables the use of multi-population dynamical models which help break the mass-anisotropy degeneracy. In addition, I use new stellar population modeling results with data from Keck/LRIS to break the degeneracy between stellar mass and the halo mass profile. With these new tools, I place NGC 1407 into the emerging picture of the relation between halo mass and the inner DM density slope.

Thayne Currie | Subaru Telescope

Multi-Wavelength Characterization of Keck-Discovered Directly-Imaged Exoplanets

We present new near-to-mid infrared photometric/spectroscopic observations that clarify the properties of two directly-imaged extrasolar planets discovered with the Keck Observatory: ROXs 42Bb and LkCa 15 b. New OSIRIS spectroscopy and NIRC2 mid-IR photometry for ROXs 42Bb yield arguably the richest data set for any imaged exoplanet to date. These data place new constraints on ROXs 42Bb's gravity, clouds, and chemistry and confirm its status as a planet-mass object. But they also reveal new tension between real planet atmospheres and model predictions that may call into question attempts to infer a jovian planet's formation mechanism by its carbon abundances. New thermal IR NIRC2 images of LkCa 15 reveal sharp images of the star's inner regions. Analyzing these data, new SCExAO/near-infrared data, and published aperture masking data, though, suggests that ``LkCa 15 b" may instead be the bright edge of an inner disk wall, not a planet. Keck will remain crucial in confirming and characterizing exoplanets, even when SCExAO is at full power, and will help pave the way for exoplanet imaging with the Thirty Meter Telescope.

Alex Krolewski | UC Berkeley

CLAMATO: Mapping the z~2 universe with 3D Lyman-alpha forest tomography

Moderate-resolution optical spectra of closely-spaced background quasars and Lyman-break galaxies can be used to reconstructed the 3D structure of the universe at z ~ 2 with comoving resolution ~2.5 h^{-1} Mpc. We present the CLAMATO survey, which aims to map a volume of 10^6 h^{-1} Mpc^3 at z~2, identifying voids, proto-clusters, and other large-scale structures, and placing galaxies in their cosmic environment at the epoch of peak star formation. We characterize the properties and evolution of three proto-clusters discovered within our field, present the first detection of voids at z~2, and measure the bias of galaxy samples at z~2 using cross-correlations with the Lyman-alpha forest. Additional applications of this work include characterizing the cosmic web at z~2 and determining the environmental influence on galaxy evolution at "cosmic noon."

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Session VII (1:15 – 2:55 pm) — *Session Chair: Marusa Bradac*

White Paper Presentations

Jean Brodie | UC Santa Cruz

Keck White Papers introduction

Jessica Lu | UC Berkeley
Enhancing Multi-Object Spectroscopy with Ground-Layer Adaptive Optics at Keck

Dmitri Mawet | Caltech
NIRC2 Upgrade

James Larkin | UCLA
New AO IFS design

Claire Max | UC Observatories
UCO White Papers

Don Neill | Caltech
KCWI Update

Ji Wang | Caltech
Detecting Methane In HR 8799 c with High Dispersion Spectroscopy Aided By Adaptive Optics

High dispersion spectroscopy of brown dwarfs and exoplanets enables exciting science cases, e.g., mapping surface inhomogeneity and measuring spin rate. Here, we present K and L band observations of HR 8799c using Keck NIRSPEC in adaptive optics (AO) mode (NIRSPAO). We search for molecular species (H_2O, CO and CH_4) in the atmosphere of HR 8799c with a template matching method, which involves cross correlation between reduced spectrum and a template spectrum. We detect CH_4 in L band data but do not detect H_2O or CO. We conduct planet signal injection simulation to estimate the sensitivity of our AO-aided high dispersion spectroscopic observations. We conclude that 10^{-4} contrast or better can be reached in both K and L band. However, the planet star contrast for HR 8799c is below 10^{-4} in K band, explaining the non-detection in K band. Non-detection of H_2O in L band is attributed to non-equilibrium chemistry, patchy cloud and a super-solar C/O ratio.

Adam Tomzcak | UC Davis
The Galaxy Stellar Mass Function: Glimpsing the Effect of Local Environment

We investigate impact of local environment on the galaxy stellar mass function (SMF) spanning a wide range of galaxy densities from the field up to the dense cores of massive galaxy clusters. Data are drawn from a sample of eight fields from the Observations of Redshift Evolution in Large-Scale Environments (ORELSE) survey, each hosting massive large scale structures (LSSs). Deep broadband photometry allow us to select samples of galaxies with stellar masses as low as 10^9 M_{sun}. Taking advantage of the high spectroscopic completeness of ORELSE (>4000 secure spectroscopic redshifts) and precise photometric redshifts, we construct 3-dimensional density maps between $0.55 < z < 1.3$ using a Voronoi tessellation approach. We find that the shape of the SMF is a strong function of local environment exhibited by a smooth, continual increase in the relative numbers of high- to low-mass galaxies towards denser environments. A straightforward implication is that local environmental density proportionally increases the efficiency of (a) destroying lower-mass galaxies and/or (b) growth of higher-mass galaxies. We further split galaxies into star-forming and quiescent subsamples using rest-frame broadband colors. Interestingly, we find that the shapes of the star-forming and quiescent SMFs show the same environmental dependence as for the total sample, although not quite as strongly for the quiescent subsample. We devise a simple toy model to characterize the connection between the SMF of field galaxies to that of denser environments.

David Fisher | Swinburne University of Technology

DYNAMO: An upclose view of turbulent disk galaxies

Observational limits to sensitivity and resolution restricts information on the turbulent, clumpy mode of star formation common at z=1-3, which is responsible for over 2/3 of star formation in the Universe. I will present results on a sample of rare galaxies at z=0.1 that are very closely matched to z=1-2 main-sequence galaxies. Using DYNAMO we can directly measure the properties of massive star forming clumps with extreme accuracy. The DYNAMO survey has heavily relied on observations from Keck including kinematics and ionized gas maps from OSIRIS, maps of stellar mass from NIRC2, and observations of outflowing gas from LRIS. I will show that clump sizes are very closely matched to straightforward predictions from theories of instabilities arising in a self-gravitating disk (i.e. Toomre instability). Moreover, I will show that relationships we observe in DYNAMO galaxies between gas fraction and gas kinematics are also consistent with the Toomre instability theory. These results provide a direct connection between star formation in the clumpy mode and natural *in situ* processes in disk galaxies. I will also discuss how the properties of clumps in turbulent disks are directly connected to fundamental parameters of galaxy evolution such as the galaxy angular momentum, as well as the molecular gas fraction and depletion time.

Session VIII (3:15 – 4:45 pm) — *Session Chair: Claire Max*

Anna Ciurlo | UCLA

Gas Dynamics at the Galactic Center

In the central parsec of the Milky Way Galaxy the environment of the supermassive black hole (SMBH) presents a complicated composition that includes a very young star cluster emitting strong UV radiation, encircled by a torus of molecular gas (the Circumnuclear Disc, CND), and crossed by tidally stretched clouds of ionized gas (the Minispiral). The question of formation of a young cluster in the hostile environment of the central parsec is still unanswered, as well as the origin of the CND and the Minispiral. We present a study of morphology and dynamics of sub-parsec scale gas features in the central region in order to disentangle the specific components and processes, and to place the gas structures in a 3D context.

Stephanie Pointon | Swinburne University of Technology

The Impact of the Group Environment on the OVI Circumgalactic Medium

The circumgalactic medium (CGM) is a vast reservoir of gas surrounding galaxies which is accreted along the major axis to fuel continued star formation and is then expelled along the minor axis to replenish the gas reservoir. However, our simplified model of the CGM does not account for the role that the environment plays in galaxy evolution. The influence of mergers or interactions on the CGM could result in changes to the flow of baryons in and out of galaxies involved, potentially quenching star formation. We compare the well-studied isolated CGM to our sample of groups of galaxies, focusing on the highly-ionised CGM at low redshifts ($z < 0.5$). Using OVI absorption profiles in Cosmic Origins Spectrograph quasar spectra and HST images we found that the equivalent width and velocity spread of absorption in group environments are significantly smaller than for isolated galaxies. We suggest that, as seen in the EAGLE simulations, the warm/hot CGM is dependent on the virial temperature of the halo, where more massive halos such as those surrounding groups of galaxies have higher virial temperatures which ionise oxygen beyond OVI. The remaining OVI likely exists at the interface between hot diffuse gas and cooler regions of the CGM in group environments.

Dimitri Mawet | Caltech

Keck Planet Imager and Characterizer: status update

The Keck Planet Imager and Characterizer (KPIC) project is a cost-effective four-pronged upgrade to the Keck II adaptive optics system, and pathfinder to future ELT high contrast imaging and spectroscopy facilities. The first upgrade module is the deployment of a high performance L/M-band vortex coronagraph inside Keck/NIRC2, the infrared (IR) workhorse camera of the Keck II AO system. The new mode has been commissioned in June 2015. The Keck/NIRC2 L/M vortex coronagraph delivered its first science results recently, and is now offered in shared risk mode. The second upgrade, funded by the National Science Foundation (NSF) Advanced Technologies and Instrumentation (ATI) program, is the deployment of an infrared pyramid wavefront sensor module based on a SELEX IR-APD camera from the University of Hawaii, enabling high contrast imaging on and around cool, red, and/or obscured objects. The third upgrade component is a compact high-contrast enabling module, adaptively corrected with a high-density MEMS deformable mirror, and equipped with an apodized vortex coronagraph specifically optimized to deal with the segmented Keck aperture. The fourth and last upgrade component is an active fiber injection unit (FIU) designed to feed the high-resolution IR spectrograph Keck/NIRSPEC via single-mode fibers. KPIC already enables the discovery and will soon enable the high-resolution spectroscopic characterization of giant exoplanets around cooler M stars, using the concept of high dispersion coronagraphy (HDC). HDC which optimally pairs high contrast imaging and high-resolution spectroscopy will allow unprecedented/detailed characterization of exoplanet atmospheres, including molecular composition, spin measurements, and Doppler imaging. KPIC will advance HDC on segmented telescope, paving the way towards the ELT planet finders and characterizers.

Gregory Walth | UC San Diego

Using Cosmic Telescopes to Study the Nebular Emission of Gravitationally Lensed Dusty, Star-Forming Galaxies with Keck

We will discuss our observational program targeting rest-frame optical nebular emission lines in Herschel-detected gravitationally lensed dusty star forming galaxies (DSFGs), using the near-infrared spectrographs; Keck/MOSFIRE, Keck/OSIRIS, LBT/LUCI, and Magellan/MMIRS. DSFGs undergo the largest starbursts in the Universe, contributing to the bulk of the cosmic star formation rate density between redshifts $z = 1 - 4$. Internal processes within high-redshift DSFGs such as feedback from star formation (SF), the role of turbulence, gas surface density of molecular gas, AGN activity, and the rates of metal production remains largely unexplored. Much that is known about DSFGs star formation properties comes from their CO emission from ALMA/IRAM, and dust emission from the Herschel Space

Observatory. However, Herschel reaches the confusion limit quickly and only the brightest galaxies at redshifts z > 2 can be detected. In order to fully understand the star formation history of DSFGs, it is necessary to observe their optical nebular emission. Unfortunately, UV/optical emission is severely attenuated by dust, making it challenging to detect. With this in mind, we have conducted the Herschel Lensing Survey, of the cores of almost 600 massive galaxy clusters, where the effects of gravitational lensing are the strongest. With the detection of the gravitationally lensed DSFGs nebular emission lines, we are able to complete the star formation picture using Keck near-infrared spectroscopy. We are conducting a new survey using OSIRIS-LGS to resolve a sample of gravitationally lensed DSFGs from the Herschel Lensing Survey (>100 mJy, with SFRs >100 Msun/yr) at redshifts z=1-4 with magnifications >10x all with previously detected nebular emission lines. We will present the physical and resolved properties of gravitationally lensed DSFGs at unprecedented spatial scales; such as ionization, metallicity, AGN activity, and dust attenuation.

Hassen Yesuf | UC Santa Cruz

Studying Galactic Winds, Stellar populations, and Gas Metallicities with Deep Keck Spectroscopy

We present highlights on the distant galaxies aspect of the multi-semester Keck HALO7D deep spectroscopic program. Our targets are galaxies at z~0.5-1.5 within the CANDELS field, where superb sets of multi-wavelength data already exist, providing key information ranging from stellar mass, star-formation and galaxy structure and morphology. Our main science goals that exploit these exceptionally deep (8 hours) spectra include:

1. Obtaining measures of galactic wind strengths and speeds from the rest frame near UV lines of galaxies and AGNs at z=0.7-1.5
2. Estimating gas metallicities of low mass galaxies at z ~ 0.5
3. Mapping the kinematics of extended star-forming galaxies from multi-slit (position angle) coverage
4. Analyzing the stellar population of quiescent galaxies at z~0.7

As part of the highlight, we will present our published results on winds in 12 X-ray AGN host galaxies at z ~ 1 and their comparison sample. We found that the median centroid wind velocity in these AGNs is -90 km/s, and the AGN winds are similar to the star formation-driven winds, and are too weak to escape and expel substantial cool gas from galaxies. Our sample doubles the previous sample of AGNs studied at z~ 0.5 and extends the analysis to z ~ 1.

Devin Chu | UCLA

Investigating the binarity of the short period star S0-2 in orbit around the Galactic center supermassive black hole

The star, S0-2, orbits the supermassive black hole in our Galaxy with a period of 16 years provides the strongest constraint on both the mass of the black hole and the distance to the Galactic center of the S-Stars. S0-2 will soon also provide the first measurement of relativistic effects with stellar orbits at the Galactic center. In this work, we report the first limits on the binarity of S0-2 from radial velocity monitoring, which has implications for both understanding its origin as well as its utility as a probe of the gravitational field around the black hole. With radial velocity data spanning 16 years, we have the baseline to look for radial velocity variations from S0-2's orbital model. We also report 8 new radial velocity measurements of S0-2. Using a Lomb-Scargle analysis, we search for a periodic signal within S0-

2's radial velocity residual curve. We detect no radial velocity variation beyond S0-2's orbital motion and do not find any significant periodic signal. In addition, we derive an upper mass limit on a companion for S0-2 for binary periods ranging from 2 to 200 days. The median upper limit is Msin less than equal to 1.8 solar masses and the maximal upper limit is Msin less than equal to 3.1 solar masses at 95% confidence for a binary period of 90.2 days. The lack of a significant periodic detection suggests the Hills mechanism is a plausible formation scenario for S0-2. We also investigate the impact of a binary system on the measurement of the relativistic redshift at S0-2's closest approach in 2018. We find that binaries can add a systematic bias to the measurement of the relativistic redshift, but plausible binaries for S0-2 will not alter a 5 sigma detection of the relativistic redshift.

Calen Henderson | Caltech

Using AO Follow-Up to Characterize Microlensing Exoplanets

The mass and distance of a microlens are degenerate, thus requiring at least two relations to yield a unique solution. Measuring the finite-source effect from the light curve helps provide one mass-distance relation for the lens system. Currently, the primary avenue for establishing a second relation and thus uniquely solving for the mass and distance of the lens is by measuring the microlens parallax. One specific implementation is the satellite parallax technique, which involves taking observations simultaneously from two locations separated by a significant fraction of an AU, and which has been employed by Spitzer and K2, transforming this methodology from a cottage industry to a booming economy. However, the majority of microlensing exoplanets to be discovered in the coming decades, up to and including the detections predicted for WFIRST, will not have a measurement of the satellite parallax, requiring another avenue for converting microlensing observables into physical parameters. Enter the lens flux characterization technique, through which a microlensing target is observed with a high-resolution facility, facilitating a constraint on the flux from the lens system. This yields a third mass-distance relation for the lens and can be combined with that from finite-source effects to determine the mass of the lens system as well as its distance from Earth. Here I will describe the lens flux method, including the timescales involved as well as the observational and analysis challenges. I will then highlight recent NIRC2 programs designed to make lens flux measurements for a myriad of exoplanetary lenses, including: (A) systems with high blend flux, which AO is perfectly suited to resolve; (B) systems with high relative lens-source proper motion; (C) free-floating planet candidates; and (D) bound exoplanets.

Posters

Fatima Abdurrahman | UC Berkeley

Focal Plane Results on 'imaka

Bruce Berriman | Caltech

News from the Keck Observatory Archive

Zheng Cai | UCO/Lick Observatory

Garry Foran | Swinburne University of Technology

Abhimat Gautam | UCLA

Adaptive Optics Study of Stellar Variability at the Galactic Center

We present a photometric study of stellar variability and search for eclipsing binaries in the central 10" (~0.4 parsecs) of the Milky Way Galactic Center (GC). Tighter constraints on stellar variability and the binary fraction of young stars can help better understand the origin and presence of early-type stars in close proximity to the central supermassive black hole at the GC. Stellar variability can also reveal specific populations of late-type stars, leading to a more detailed understanding of the composition of the nuclear star cluster. This study uses adaptive optics (AO) data collected with the W.M. Keck 10 m telescope in the K'-band (2.2 μm) over 35 nights, spanning an 11 year time baseline. Our analysis shows that at least ~34% of the stars in our sample display variability. With our periodic variability search, we find an eclipsing binary fraction of 2.1 ± 1.5% among spectroscopically-confirmed early-type stars. We additionally find a periodically variable star with a period of ~ 40 days, suggesting a metal-poor Type II Cepheid variable or an ellipsoid binary system.

Jaqueline Keane | IfA, University of Hawaii

Small Primitive Bodies Test the Predictions of Solar System Formation Models

Small primitive bodies were witness to the solar system's formative processes. When gas was present in the disk during the first 5 million years, a local chemical signature was imprinted on the planetesimals. The connection to today's solar system relies on how this material was dynamically re-distributed during planet formation. To connect early planet formation to the modern era, we must measure the compositions of a range of primitive objects from different locations in the solar system and compare them with the predictions from models of early solar system formation. Modern dynamical models of planetary growth can reproduce much of the solar system architecture, but differ significantly in their predictions regarding planetary migration, source of volatile materials in the inner solar system, and movement of small bodies. Using several astronomical facilities/instruments, our team is undertaking a program to characterize the composition and drivers of activity in a variety of small solar system bodies; comets, main belt comets, and Manxes. Our ultimate long-term goal is to use these unique datasets to trace the distribution and abundance of volatiles in the early solar system to compare to solar system dynamical models to gain an understanding of how these materials become incorporated into habitable worlds. Here we present an overview of recent observational highlights. (1) Using Keck2-NIRSPEC spectroscopy to quantify volatile production rates of active comets, combined with optical wavelength photometry, we determine the abundances of key volatiles and estimate the onset of activity in comets. Through datasets that include Keck2-NIRSPEC, the Spitzer large comet nucleus survey, the NEOWISE small body survey, the Pan-STARRS1 survey in Hawaii, we now have sufficient information to model comet heliocentric activity over many apparitions to understand the basic volatile compositions and look for trends that can be tied to orbital properties. (2) A Manx is a small body on a long-period comet orbit that is inactive or minimally active at small perihelion distances (where water would be expected to be strongly sublimating), resulting in the lack of a significant tail. These objects are being discovered at a rate of about a dozen per year from large all-sky surveys, and Pan-STARRS1 in Hawai'i is the most prolific at discovering these weakly active objects. These bodies could represent inner solar system material that was ejected into the outer solar system during planet migration and is now migrating in. We are characterizing a set of Manxes to assess signs of activity, as well as classifying their surface materials, to test solar system model predictions that there should be inner solar system material in the Oort cloud.

Molly Kosiarek | UC Santa Cruz

Masses and Radii of K2-3 and GJ3470 from Radial Velocity Measurements and Spitzer Transits

We report masses and densities for two planetary systems, K2-3 and GJ3470, derived a combination of new Keck HIRES radial velocity measurements and previous HARPS and PFS measurements. K2-3 is a bright, nearby M0 dwarf star hosting three super-Earth planets between 1.5 - 2 Earth-radii at orbital periods between 10 and 45 days. GJ3470 is also a bright, nearby M dwarf hosting one 4 Earth-radii at an orbital period of 3.34 days. Due to their low densities and bright host stars, these planets are ideal candidates for transmission spectroscopy with JWST and HST in order to characterize their atmospheric compositions.

Francisco Müller-Sanchez | University of Colorado, Boulder

The Keck OSIRIS Nearby AGN Survey: The Role of AGN-driven Outflows in the Evolution of Seyfert Galaxies

I will present the scientific goals and first results of the KONA (Keck OSIRIS Nearby AGN) survey, which uses the integral field unit OSIRIS plus LGS-AO to probe down to scales of 5 parsecs in a sample of 40 Seyfert galaxies. I will describe recent work showing how AGN interact with their host galaxies. We find that AGN-driven outflows of ionized gas are ubiquitous, and that biconical models of radial outflow provide a good fit to the spatially resolved kinematics. The mass outflow rates are 2-3 orders of magnitude greater than the SMBH accretion rates, but are comparable to the estimated inflow rates to the central 25 pc, suggesting that AGN feedback suppresses accretion onto the SMBH and that AGN feedback has a strong impact on the turbulent ISM near the SMBH, probably disrupting the conditions for star formation. Finally, with complimentary Chandra and HST images our observations establish whether or not the outflow extends deep into the host galaxy, and provide direct evidence of the ways in which the outflows of ionized gas interact with the circumnuclear ISM, either by creating cavities of molecular gas, or by launching molecular outflows.

Nicole Wallack | Caltech

A deep search for planets forming in the TW Hya protoplanetary disk with the Keck/NIRC2 vortex coronagraph

Gap features in the nearest protoplanetary disk, TW Hya (distance of 60 pc), may be signposts of ongoing planet formation. To test this hypothesis, we performed long-exposure thermal infrared coronagraphic imaging observations to search for accreting planets within dust gaps previously detected in scattered light and submm-wave thermal emission. Three nights of observations with the Keck/NIRC2 vortex coronagraph mode in L’ (3.4-4.1 um) did not reveal any statistically significant point sources. We thereby set strict upper limits on the masses of non-accreting planets. In the four most prominent disk gaps at 24, 41, 47, and 88 au, we obtain upper mass limits of 1.6-2.3, 1.1-1.6, 1.1-1.5, and 1.0-1.2 Jupiter masses assuming an age range of 7-10 Myr for TW Hya. These limits correspond to the contrast at 95% completeness with a 1% chance of a false positive within 1 arcsecond of the star. Our non-detection also implies that any putative 0.1 Jupiter mass planet, which could be responsible for opening the 24 au gap, is presently accreting at rates insufficient to build up a Jupiter mass within TW Hya's pre-main sequence lifetime.

Poh-Chieh Yu | Graduate Institute of Astronomy, NCU, Taiwan

The Keck/OSIRIS Nearby AGN Survey: Investigation of Hidden Broad-Line Region (HBLR) and Non-HBLR Seyfert 2 Galaxies

Detections of the polarized broad-line region in local Seyfert 2 galaxies (HBLR Sy2s) provided evidence for the torus unification model of AGN. However, only about 40% of Seyfert 2 have HBLRs, implying non-HBLR Sy2s might not fit the unified scheme. For example, the non-HBLR Sy2s might be at different evolutionary stage. However, interpreting the observational data can be affected by possible contamination from the central AGN. By using adaptive optics with an integral field unit, the KONA (Keck OSIRIS Nearby AGN) survey allows us to resolve the central few hundred parsec region with ~40 parsec resolution and to reduce the contamination of the AGN continuum. Our preliminary fits to the stellar continuum indicate that the HBLR Sy2s may have more young stars than the non-HBLR ones. Also, it seems that the non-HBLR Seyfert 2's tend to have jet-like structures of H2 and Br-gamma emission, while the HBLR ones show compact cores. This suggests that the non-HBLR Seyfert 2's might be more similar to LINERs, which also have more powerful jets. Further analysis including increasing the sample and analyzing the kinematics will be conducted in the future.

Cover photo by Laurie Hatch