Importance of UCO Facilities (from UCO Survey 1)

December 2012

A questionnaire was sent to all users of UCO telescopes for the past three years, asking about the role that UCO facilities played in their coming to UC, remaining at UC, in their research at UC, and in related activities such as education, outreach, and fund-raising. These are the full replies.

Gillian Wilson, UC Riverside

UCO facilities are vital to my research, allowing me in recent years to study field galaxies (DEIMOS), and distant clusters of galaxies (LRIS and MOSFIRE). These world-class multi-object spectrographs are essential for studying distant, faint galaxies in large numbers.

At time of hire, I was fortunate in being able to choose between several offers. **Access to UCO facilities was one of the most important factors in my decision. Without UCO access, I would be highly likely to move to another institution.**

I am heavily involved in outreach, giving K-12 talks, radio and press interviews etc. See e.g., http://faculty.ucr.edu/~gillianw/publicoutreach.html

I invariably show and discuss the latest UCO findings in these outreach efforts (both results from my own and other groups).

I also utilize UCO findings in teaching my classes (at all levels from large undergraduate classes for non-science majors to specialized courses for graduate students).

[**UCO facilities] provide world-class data/projects to my postdocs and students.**

Eliot Quataert, UC Berkeley

I am a theorist who has had 2 Keck nights for observational time closely related to my theoretical work. However, the observational time has been only a very small part of my research program.

Insofar as the UCO facilities help recruit outstanding faculty and students, they have been extremely important -- even though my own research does not rely heavily on the facilities themselves.

Marc Davis, UC Berkeley

My research, for example the DEEP2 survey, is obviously dependent on the Keck telescopes. This survey has led to enormous use by all astronomers who are interested in deep fields.

The large telescopes that were planned at UC by Jerry Nelson were instrumental in convincing me to come to Berkeley, 30 years ago. I don't regret it!

My students, who have done very well in the job market, have generally worked with me on projects with the Keck telescope. As such the Keck telescope served as a strong educational tool.

I talk about the Keck telescopes in my classes and show them some of my data. Thus the students can see how astronomy works, giving them a sense of what a magnificent field I work in!

Saul Perlmutter, UC Berkeley-LBNL

The Keck telescopes, the instrumentation labs that have built the instruments for the Keck telescopes, and the remote observing rooms for the Keck telescopes have all played a crucial role in my research work. Almost all of the work leading up to the discovery of the acceleration of the universe depended in a fundamental way on these facilities, and in that sense, the Nobel Prize in Physics in 2011 owes a large debt to these UCO facilities.

When other universities have offered me positions over the years, one reason that their offers have not been as attractive was that most of them do not have comparable astronomical capabilities. Similarly, **we found in recruiting faculty that it makes a big difference for them to know that they have a world-class facility that they would have special access to and possibly the capability of producing new instrumentation for their particular experiments and projects.**

Alice Shapley, UCLA

My astronomical research is primarily based on Keck imaging and spectroscopic observations of distant galaxies. Basically all of the research papers from my group feature Keck data. The instruments we have used are the LRIS spectrograph and imager, the NIRSPEC spectrograph, the OSIRIS integral field unit spectrograph, and the brand-new MOSFIRE spectrograph. Of particular note, several UC colleagues and I are now commencing a major survey with MOSFIRE, which we hope to have a significant impact on our understanding of high-redshift galaxies.

Access to Keck instrumentation was one of the primary reasons I left a tenure-track position at Princeton University (I was an assistant professor there for 2.5 years before being recruited to UCLA) and is one of the primary reasons I would not consider moving to a different, non-Keck institution.

I have trained my graduate students in observations and reduction of Keck data. I have also given a Keck public lecture to local Hawaii residents.

Spencer Stanford, UC Davis

The UCO facilities, in particular the Keck telescopes, have been one of the most essential elements of my research program over the past 15 years. The large apertures of Keck coupled with high throughput multiplex spectrographs have allowed me to pursue the primary goals of first discovering and then understanding the formation and evolution of galaxy clusters at the highest redshifts. Without access to the Keck telescopes I would never have been able to carry out the science that I love.

Having access to the Keck telescopes is the primary reason that I wish to remain at a UC institution. The high quality of the UCO facilities attracts some of the best graduate students, which provides a high degree of motivation for myself as a mentor to teach students about the fundamentals of observational astronomy.

Joshua Bloom, UC Berkeley

All but the UCSC Adaptive Optics Lab and Visitors Center have played an important role in my work. The Keck Telescopes, operated by Keck Observatory, are a wonderful shared resource that we are privileged to use as faculty members. The access to Keck has not always been easy (of course) but it has been quite useful for time-domain science. **The 40inch at Mt Hamilton has been great as a calibration tool. I also was fortunate enough to get to use the 40inch to commission an instrument I built (testing a new detector technology).**

Getting access to Keck was a critical deciding factor for me [to come to UC Berkeley]. I've not gone through a retention case.

I brought several classes from intro astronomy courses from Cal to Mt Hamilton. Those were obviously very special moments for them in their studies, as many of them had not seen a telescope up-front nor really understood them to be scientific laboratories.

The remote observing rooms transformed the way I observed with my students and postdocs. It has made the teaching/didactic nature of our mission that much easier.

Keck and Mt Hamilton are precious scientific resources for the people of California.

Ben Zuckerman, UCLA

Beginning in the mid-1990s, the Lick and Keck telescopes have been essential to the research program of my students and myself. Some of their thesis research and some of our most cited papers stem from data obtained at these telescopes. I went back to my list of refereed publications since I arrived at UCLA. I count at least 14 refereed papers that used data from Lick and at least 35 papers that contain Keck data.

Having access to Keck, and to a lesser extent Lick, is a strong motivation not to leave UCLA.

I have given quite a few public lectures on astronomy in which I describe results obtained at UCO facilities.

UCO facilities have enabled my UCLA colleagues and me to establish that at least 25% of white dwarf stars are orbited by (complex) ancient planetary systems, and to characterize the bulk elemental composition of rocky planetesimals and planets that orbit around other stars. UCLA is the world leader in such research that cannot be matched (or even approached) by any other technique.

We are also (arguably) the world leader in identifying and characterizing young stars near Earth. Such research is critical for direct imaging programs for extrasolar planets. The Keck telescope has played an important role in young star research. For example a 1999 UCLA paper based on Keck observations – and part of the PhD thesis research of my former student Richard Webb -- is probably the most cited paper in this field.

Keck and UCLA played a large role in the 2008 Science and 2010 Nature papers that reported the massive, extended, 4-planet system that orbits the star HR 8799. The Science paper, along with another paper, received the oldest award given out by the AAAS as the best paper to be published in Science magazine during a recent 12-month interval.

Peter Nugent, LBL

The Keck and Lick 3-m telescopes have been fundamental in my research since coming to California 16 years ago. From pursuing the Nobel awarded research on the accelerating universe to following the closest supernova in a generation, these facilities have provide my research groups everything to stay ahead of the competition in my field.

Access to the facilities has definitely played a role in my staying at UCB and LBNL in the past 5 years.

The discoveries made have generated a lot of public interest and has allowed me to speak to the value of science in general and astronomy in particular to everyone from children in grade schools to the public at large.

Raja GuhaThakurta, UCSC

The Keck telescopes and their spectrographs (LRIS, ESI, HIRES, and, most of all, DEIMOS) have been the primary instruments I have used for my main area of research: near-field cosmology. This has involved detailed studies of the structure, dynamics, tidal effects, ram-pressure stripping, star-formation history, and chemical enrichment of galaxies in the Local Group and Local Volume through measurements of their resolved stellar population or integrated light in order to understand their formation and evolution.

The SPLASH survey of the Andromeda galaxy involves a large international collaboration that is led by our UCSC group. This decade-long survey has shaped/defined my career and helped me realize my goal of using M31 to understand the physical processes that shaped large spiral galaxies like the Milky Way.

I was a member of the DEEP2 and DEEP2 redshift survey teams and of the AEGIS collaboration whose backbone was the DEEP2 redshift database. These two surveys of distant galaxies were carried out with the Keck II telescope and DEIMOS spectrograph.

The Lick Shane 3-m telescope and KAST spectrograph have been useful to me as well for two low surface brightness spectroscopic studies. The first was a study of optical cirrus (reprocessing of ambient starlight by diffuse optically thin dust clouds) to gain insight into the physical processes associated with energy balance in the interstellar medium. The second was a spectroscopic study of the outer regions of a volume-limited sample of elliptical galaxies to better understand galaxy-scaling relations. This formed the PhD thesis of Justin Howell.

The prospect of carrying out my observational research using the Keck and Lick telescopes played a big role in my decision to leave a tenure-track job at STScI to come to UCSC.

The training and education of young people is of vital importance to me. All of the 11 UCSC PhD students I've supervised and the 6 post-doctoral fellows at UCSC I have worked closely with have relied primarily on Keck and Lick data. This has also been true of most of the other young people I have mentored: **a dozen or so UCSC undergraduates, a dozen or so graduate students and postdocs outside UCSC, and the ~ 30 high-school students in the Science Internship Program at UCSC.**

The Keck Evenings with Astronomers talk series, the Mount Hamilton Music of the Spheres concert series and Summer Visitor Program, and fundraising events at these two observatories have given me the opportunity to develop my public speaking skills.

Daniel Kasen, UC Berkeley

My research focuses on supernovae and other explosive transients -- events that are usually dim, distant and fleeting, and so require large telescopes and the quality access that UCO facilities provide. Many of the major recent developments in my field have in fact involved UCO resources (e.g., spectroscopy of an extremely nearby Type Ia supernova, detection of hydrogen in a Type Ia supernovae, observations of light echoes from supernova remnants, to name a few). Though my role is primarily as a theorist, these observations in large part drive my research program, as they have established the pressing questions in the field and provided the data we use to validate or falsify numerical simulations. The UCO facilities have also broadened my program by allowing me to get directly involved in observations myself. Overall, the quality/relevance of my work is reliant on having a strong connection between observations and

models, which is an example of how the world-class UCO facilities strengthen not only the observational work, but also the theoretical program at UC.

A major factor when I was deciding on a position (~3 years ago) was the strength of the observational community. UC Berkeley upstaged all competitors as a premiere institution for transient astrophysics, which is due to the resources of UCO and the talent they have attracted. The opportunity to collaborate with observers, to have access to data from the UCO facilities, and to engage in observing myself, where all taken as major advantages in my research program, and something that I did not find equaled elsewhere. **I would therefore emphasize that maintaining the strength of UCO facilities is critical not only for drawing and retaining observers, but theorists as well.**

Leo Meyer, UCLA

The Keck telescopes are absolutely crucial to my research. My research focuses on the properties of the supermassive black hole in the center of our Galaxy, a source that can only be resolved with 10-meter class telescopes equipped with adaptive optics.

Without the Keck telescopes, coming to UCLA would not have been an option. On the other hand, given the worldwide leadership of Keck Observatory in Laser Guide Star Adaptive Optics, UCLA with its access to the observatory and its Infrared Lab is clearly my favorite place to be.

Having the UCLA Infrared Lab is incredibly helpful in my research. Distinguishing signal from mere noise in a cutting edge data set requires a deep understanding of the instruments. Many instruments at Keck Observatory have been built under the leadership or in collaboration with UCLA's infrared laboratory. Having the scientist (instrument users) in the same building as the instrument builders proves extremely valuable.

Bruce Macintosh, LLNL

Access to UCSC AO lab has enabled student-sized research projects that allow grad students to develop practical skills, broadly applicable in industry/optics/medicine, during their Astro PhD programs. Techniques developed there, in collaboration with LLNL, will be applied to nationally vital science resources such as synchrotron or linac x-ray sources, lasers, etc.

UCSC AO lab was crucial in developing technology that enabled the Gemini Planet Imager, a $24M research instrument constructed and integrated primarily within UC.

I'm currently considering a faculty position at another institution - one major factor in favor of staying within UC (offsetting a number of other factors) is the access to Keck.

Resultant awards/recognition: AAAS Newcomb Cleveland Prize, for use of the Keck telescope to discover the HR8799 system

Adam Burgasser, UCSD

I decided to move from an MIT faculty position to UC because of the access to better telescope facilities and plan for investment in the 30-meter telescope.

Keck/NIRSPEC is the only instrument in the world with which my science program (radial velocity variability of the lowest-mass stars and brown dwarfs) can be done. Given the long-term nature of this program (orbital periods of 0.5-2 years), it is critical that regular access to Keck is possible through UCO. The Lick Observatory is also critical to my educational work at UCSD; we lack access to a small telescope in southern California, so Lick is our primary resource for introducing undergraduate and graduate students to observational astronomy and training them in imaging, spectroscopy and polarimetry techniques. We will have the first regular

Astronomy Lab at UCSD this coming winter term, and its success hinges on our remote access to Lick Observatory.

The coherence of the UCO has enabled a greater ability to collaborate on my science than was possible at my prior institution. Few departments have significant star-brown dwarf research programs, but the integrated expertise across the UC system through UCO has allowed me to find partners in my science and instrumentation interests. I also believe I have a greater impact on more students in the UC (and by proxy the CSU) system, in terms of engagement in science, mentorship and training.

It might be good to emphasize the **publication statistics of UCO faculty** compared to other physical science fields (may be an apples to oranges comparison though); **we should also mention how many prize postdocs we attract (Hubble, Spitzer, Sagan, etc.).**

My binary work with Keck/AO and Keck/NIRSPEC has resulted in invited talks at international conferences and a Hellman Fellowship grant at UCSD.

Tomasso Treu, UCSB

[UCO facilities] are essential to my research program. The Keck and Shane telescopes and cutting edge instrumentation, much of which has been developed at UCO labs, provide essential data for my studies. **I would not have applied to UCSB if UCO facilities had not been available**.

UCO facilities are an integral part of my mentoring of students and postdocs. All my students, including undergraduates, get to experience the thrill of research with the best data on Earth and publish papers. I use the remote observing rooms very effectively for training purposes. I incorporate data and results from UCO facilities into my lectures and public lectures. **UCO facilities are essential for my research and publications.** Therefore, they play an important part of my professional achievements. Much of the research that motivated my award of the AAS Newton Lacy Pierce Prize for example was based on UCO facilities.

Steve Vogt, UCSC

These facilities are crucial to all my research. Access to the world-class observing facilities at Lick and Keck were the main reason I came to Santa Cruz, and the only reason I stayed for 34 years. I turned down several offers over my career to become a director at other observatories. I stayed at Lick mainly because they provide me frequent and sustained access to cutting-edge observing facilities.

I have been very honored to be the P.I. of a $10M DOD-funded California Planet Finding Telescope project, a Congressionally funded project that gives the State of California one of the most powerful planet-hunting facilities in the world.

The outstanding Labs facilities and technical support crew at UCO/Lick has enabled me to develop several generations of world-class facility instruments with which I and my many UC colleagues have been able to carry out cutting edge forefront research.

The technical facilities and support staff at UCO/Lick have pushed UC astronomy to the very forefront of ground-based Optical and IR Astronomy, and enabled many UC astronomers to become world leaders in their respective sub-fields. The telescopes and instrumentation that is enjoyed across the UC system was mostly born and built at Santa Cruz, and in most cases defines the state-of-the art of such instrumentation.

Resultant awards/recognition: Carl Sagan Award, Tinsley Award of the AAS, Grand Prix Lallemand of the French Academy of Science, Muhlmann Award, US-Israel Bergmann Prize, UCSC Faculty Research Lecturer, U. of Texas Alumnus of the Year Award

Crystal Martin, UCSB

Keck Observatory is my primary source of data for research. I have used Lick Observatory as an instructional resource for undergraduate teaching and graduate training. I came to UC because of its role in Keck Observatory. I remain at UC because of its involvement in TMT.

By serving on committees that support UCO (director search, advisory committee, instrument development, Keck steering committee), I have become much more aware and appreciative of **UCO's contribution to every campus, the state, and the nation. These facilities enable us to attract the best graduate students and postdocs.**

UCO is at a critical juncture. It should take on a larger and better-funded role in the TMT era. Some re-organization and better accounting practices are needed, however, to prepare for this upcoming era of growth.

Resultant awards/recognition: Packard and Sloan fellowships

Arthur Wolfe, UCSB

UCO facilities are essential to my program and were a major factor in my coming to UCSB. UCO facilities allowed me to train several students who received PhDs based on Keck data. UCO facilities play a crucial role in recruitment of the top astronomical institution worldwide.

Resultant awards/recognition: 1. Elected as fellow of American Academy of Arts and Sciences. 2. Jansk prize from the NRAO. 3. Elected fellow of the American Association for the Advancement of Science.

Jean-Luc Margot, UCLA

I am a planetary astronomer and I use large telescopes in 80% of my research endeavors. **One of the most important factors in my decision to move to UCLA in 2009 was UC's privileged access to Keck.**

Outreach/mentorship enabled by UCO facilities: Training of graduate students.

Michael Rich, UCLA

One of my critical career goals has been the measurement of the composition of the Galactic bulge, and understanding the assembly of the halo of the Andromeda galaxy. Access to Keck II/nirpsec and Keck II/HIRES was critical in achieving the goal of studying the bulge. Use of HIRES resulted in two highly cited (>100 citations) papers on the composition of the bulge (Fulbright, McWilliam, & Rich 2006, 2007). As a result of my access to Keck and nirspec, Dr. Livia Origlia (INAF-Bologna) approached me to collaborate. Over 30 refereed papers later, we are still going strong. Our papers on the composition of the bulge from infrared spectroscopy are also highly cited, and Livia is a frequent visitor at UCLA. **I believe that Keck access figured in my roughly $750,000 of NSF support received since coming to UCLA.**

Access to Keck/DEIMOS enabled me to be a participant in the PANDAS project on the halo of M31. This project has resulted on over 10 refereed papers and 2 Nature papers (including 3 January 2013, on the cover of Nature). This international collaboration has also brought Michelle Collins to UCLA as a collaborator on 3 occasions and it has deepened this important international collaboration.

Access to Lick enabled me to work with Sebastien Lepine on his nearby star catalog. We have done extensive imaging and have also discovered new binary star systems using the Lick AO

system. We have jointly published over 20 refereed papers**. This collaboration has also resulted in roughly $100,000 in funding for my research.**

Access to Keck was the major reason I came to UCLA. Only with Keck was it possible for me to obtain high dispersion spectroscopy of giants in the Galactic bulge. Among persons who have worked with me, due to Keck, are Andreas Koch, Samir Salim, Will Clarkson, Christian Johnson.

Access to Keck has attracted graduate students and postdoctoral researchers to work with me, enabling me to be a mentor. Access to Keck also makes my **public presentations** more interesting and has been a factor in drawing the public to attend talks.

I have been involved in research using the Hubble Space Telescope. I am committing to use Keck to follow up (with DEIMOS and LRIS spectra) any stars in the globular cluster M4 that are shown to have astrometric wobbles and possible dark (black hole) companions. **The access to Keck was instrumental on my being selected to join the research team, and has resulted in $130,000 in funding.**

The advanced technology of Keck Observatory exemplifies the contribution of the University of California to the state, in the sense of UC originating the most cutting edge technology and ideas in the world. There are derivative benefits to the economy and to inspiring students to study in the STEM fields.

Manoj Kaplinghat, UC Irvine

This note is mainly to emphasize that UCO observatories impact not just Astronomy research but also particle physics. I am an astrophysicist working on understanding the particle nature of dark matter and data from Keck has played an essential role in this endeavor.

Recently, my group collaborated with the Fermi collaboration to look for signals of dark matter annihilation in the satellites of the Milky Way. No signal was detected but this led to a large class of canonical thermal dark matter models being ruled out. These are the kinds of models that the Large Hadron Collider and direct dark matter searches are testing. Keck played a significant role by supplying radial velocity measurements of stars in some of the satellites of the Milky Way. On a related note, Keck observations have also led to the discovery of the faintest galaxy (Segue 1) and the realization that the central dark matter mass density in all the Milky Way satellites are essentially the same. Neither of these two conclusions can yet be explained and they could impact our understanding of the particle nature of dark matter.

Jean Brodie, UCSC

Originally the Shane telescope at Mt. Hamiliton was a key factor in my coming to UC. The Keck telescopes were a crucial factor in developing a career-long research program and commitment to UC.

Without the Keck telescopes my research program would not have been feasible. The SAGES group would not have been formed, and multiple students and postdocs would not have been trained and gone on to their own faculty positions with their own students and postdocs. **We are now a multinational group with high impact in the fields of extragalactic globular clusters and galaxy formation. First the Shane and then the Keck telescopes have enabled this entire enterprise.**

Having access to world-class facilities enables first class research and fosters collaborations worldwide. It attracts the best postdocs, students and collaborators. It

provides experience that prompts invitations to serve on oversight committees here and overseas, thereby increasing the influence and visibility of UC.

Numerous NSF grants have supported my group's research for many years, the research itself being enabled by being UC faculty with access to world-class people and facilities.

Resultant awards/recognition: Major NSF grants, HST time/grants, Chandra, etc. Invitations to Chair major oversight national and international committees, invitations for SOC membership, invited talks at conferences, etc.

Lori Lubin, UC Davis

The Keck Observatories (and the future TMT) were one of the primary reasons that I accepted a faculty position at one of UC's non-flagship schools. All of my research over the past 15+ years (including for example active grants totaling over $1M over just the past 3 years) has involved the Keck telescopes. As a result, these facilities have been essential to me.

Having access to the UCO facilities and the resulting observational data significantly factors into my undergraduate teaching and outreach to K-12 schools**. The UCO facilities are essential for recruitment of new faculty and graduate students.**

Resultant awards/recognition: Awarded the UCD's Chancellor's Fellowship as a result of my research, largely involving the UCO facilities.

Eric Becklin, UCLA

I came to UCLA in 1990 to become part of the Keck user community and to work with Ian McLean to develop and the IR instrumentation lab at UCLA. UCO has helped make both of these goals possible. **My scientific work on Keck has gone way beyond my expectations because of the development of the first class near IR instruments for Keck and the additional bonus of the Keck Adaptive Optics (AO) system, one the best operational AO systems on the worlds largest telescope.** UCO had an important component of both developments.

My primary research over the last 15 years has been the study of the very core of the Milky Way and the search for substellar objects that can be imaged. Both of these research programs required the diffraction limit at 2.2 microns of the Keck telescopes. The discovery of a massive Black Hole in the core of the Galaxy, in collaboration with Andrea Ghez and Mark Morris, could not have been done without Keck and the supporting instrumentation. Likewise, in collaboration with Ben Zuckerman and others, the first imaging of Brown Dwarfs and Exoplanets required the Keck and AO.

I am Chief Scientist on the SOFIA project, a 2.5-meter telescope that flies in the stratosphere to make Infrared measurements. UCO though the support of the UCLA IR lab and commissioning on the 3-meter has been critical to the development of one of the 7 instruments (FLITECAM). UCO has provided support for our mirror coating facility and cleaning through Bill Brown. Finally, our CCD guide cameras have been greatly aided in their development through use and commissioning on the 1-meter.

Ian McLean, UCLA

I joined the faculty at UCLA t3 years ago specifically to be part of the great astronomical adventure that was the Keck Observatory. Without UCO leadership, ingenuity and funding, this remarkable Observatory could never have been as successful as it is**. The opportunity to build state-of-the-art instruments for Keck Observatory, with UCO support, was the primary**

reason why I left my tenured position at the Royal Observatory Edinburgh and joined this community.

I am a current active user of the Keck telescopes and a past frequent user of Lick Observatory. My research area is infrared (IR) astronomy. As Director of the Infrared Instrumentation Lab at UCLA, I am also involved in the development of IR instruments for Keck, Lick and other facilities. All currently operational IR instruments at Keck (NIRSPEC, NIRC2, OSIRIS and MOSFIRE) involved my group. We receive $300K per year from UCO to support the IR Lab. With UCO support, the IR Lab has lasted 23 years and has provided four major instruments and two minor cameras to Keck Observatory as well as a twin-channel camera to Lick Observatory. I**n addition to providing powerful IR instruments for our community, I have had the opportunity to mentor and train many outstanding young instrumentalists, a breed of astronomer that seems scarcer today than ever before.** I am a full-time member of the teaching faculty at UCLA and the current Vice Chair for Astronomy.

I have an extensive international reputation as an instrumentalist. I am the author of "Electronic Imaging in Astronomy" - now in its 2nd edition - which features many of the innovations in detectors and instruments pioneered by UC scientists. I am the only faculty member not from UC Santa Cruz to become Chair of the Keck Science Steering committee. During the development of the MOSFIRE project for Keck I collaborated with Prof. Harland Epps of UCO. He developed the optical design for MOSFIRE and during the project we used the facilities of the UCO optical and mechanical shops to supplement the work being done at UCLA and Caltech. My IR Lab colleagues James Larkin and Mike Fitzgerald also benefited from UCO test facilities when we delivered the Integral Field Spectrometer for GPI to Santa Cruz. System integration and testing is under way by the PI, Bruce Macintosh - a former IR Lab PhD - prior to shipping to Chile.

I consider UC Santa Cruz to be the center for the development of Adaptive Optics (AO) within the UC system. AO is critical to the future of Keck Observatory and the TMT. **At UCLA we stand ready to provide new state-of-the-art AO instruments but we rely on UCO to take the lead in developing the AO system architecture.** The collaboration between UCO and the Lawrence Livermore National Lab has been very successful.

Mark Morris, UCLA

I came to UCLA well before the Keck telescopes were built, and have only occasionally used the Lick Facilities. WMKO has become an important part of my research since the mid-90s, and I have not even remotely considered going elsewhere. The last time I seriously considered an option to go elsewhere, about 20 years ago, the accessibility of WMKO for my research had a positive impact on my decision. The Keck Telescopes have been essential to my study of the Galactic center; I have used NIRC2 and OSIRIS to study the activity of the central black hole, the massive young clusters in the Galactic center region, and the circumnuclear disk.

My research with Keck has led me to participate in outreach activities and to commit a considerable amount of time to some service activities in recent years, in support of the Keck Observatory's instrumentation and fund-raising programs. **My entire education in optical/IR astronomy was with UCO facilities, since I came to UCLA as a radio/millimeter astronomer and theorist without substantive experience as an optical/IR observer. These resources have completely opened my intellectual horizons.**

Our ability to hire some of the world's top astrophysical researchers has been very profoundly influenced by UCO facilities.

Chris Fassnacht, UC Davis

When I was looking for faculty positions, preferential access to a large ground-based telescope was one of my most important criteria. Since the Keck Observatory offers two of the largest optical telescopes in the world, my goal was to obtain a position at UC or Caltech.

The UCO facilities, in particular the Keck Telescopes, are essential for my research into galaxy structure and evolution. In particular, one of my major research efforts utilizes the adaptive optics (AO) system on Keck to obtain images of distant galaxies that are often sharper and more useful than images obtained with the Hubble Space Telescope. **I recently attended a workshop on the future of AO, and several experts from competing observatories admitted to me that Keck currently has the best AO system in the world, and that they are working hard to catch up.** This premier system has produced impressive results from my research, and has already led to one Nature paper.

I have been able to use data obtained with Keck and Lick to train both undergraduates and high school students (through the COSMOS program -- the California State summer school for mathematics and science http://cosmos-ucop.ucdavis.edu/main/campus_programs) in the fundamentals of research in science.

Marusa Bradac, UC Davis

The facilities have been a major pull in my decision to apply and take a job at UC Davis. Keck telescopes are essential for my research since we study z>~7 galaxies through spectroscopy. Keck Telescopes, and especially the MOSFIRE instrument are the only facilities in the world that are capable of such exploration.

The facilities attract students; graduate and undergraduate. I have presented my work in many of my classes. Furthermore I have used data from Keck for the COSMOS program, which is a K-12 summer program for extremely gifted high-school students. The students also visit Lick facilities during their stay.

Having access to Keck has been instrumental in obtaining telescope time on space-based facilities (Spitzer). **UCO facilities have been instrumental to me in all stages of my research. I am extremely glad to have access to these.**

Walter Harris, UC Davis

The facilities on Mt. Hamilton are key to my ongoing program of instrument development and ultimately will be essential as an observing site for diffuse emission line target monitoring. The availability (or potential lack thereof) is a VERY important factor for me. Oddly in my case this is primarily focused on what would be otherwise viewed as the least powerful telescope in the entire system. However, **the uniqueness of that facility, especially with planned or completed closures of similar resources by NOAO and NSO, gives it particular relevance** to me.

Access to UCO facilities has been very helpful for establishing new collaborations outside of the UC. This has led to new research lines and several successful grant proposals.

With the era of government-supported small aperture observatories reaching an apparent end, the only remaining resources for training new astronomers, field testing new instruments, and pursuing science programs that do not require large (8+ meter) telescopes are now found at the few universities (e.g. UCO, Texas, Arizona) that maintain them internally. This is an important niche that both provides a competitive advantage for the UC to attract new scientists and an essential service to a community that has (in my opinion) made the decision to trade its future for few big mirrors. ***As the UC considers the future of its observatory system, it should attach***

appropriate weight to the pedagogic and technology development value of its smaller facilities.

Matt Richter, UC Davis

The UCO facilities most important to me are the Keck Observatory, the UCLA Infrared Labs, and the Keck Remote Observing Room at UC Davis. In truth, none of these facilities are essential to my research, but their existence is certainly important.

For context, I am a soft-money researcher at UC Davis whose major research involves infrared instrumentation, particularly construction of high-resolution spectrographs for the mid-infrared. This work takes the majority of my time and prevents my participating in typical "observe/analyze/publish" astronomy research. While UC as a whole does not currently place much emphasis on the mid-infrared, the observational research I am able to do is aided by UC facilities.

The Keck Observatory is, of course, a major contributor to the success of UC astronomy. I have used NIRSPEC, the near infrared echelle spectrograph, for several projects. The instrument provides broad wavelength coverage with relatively high spectral resolution, which is well suited for studying molecules in protostellar environments. Access to NIRSPEC on Keck has allowed me to contribute to collaborations that might otherwise have been unavailable to me (current work studying HF, past work studying CO). I expect to continue to use NIRSPEC in the future and am participating in the study for possible NIRSPEC upgrades.

The UCLA Infrared Labs are quite important to me both for the instruments they produce and for the sense of community they foster. The members of the Labs are top-notch instrumentalists and they produce world-class instruments for the Keck Observatory. NIRSPEC, MOSFIRE, and OSIRIS are all very successful instruments that provide important capabilities. I know that their expertise is available to me for informal consultation when I am dealing with a specific issue.

The Keck Observatory Remote Rooms save money and time and help to train students. I have even used the Remote Room as a graduate student recruitment tool. I make it a point to encourage students to participate in observing as much as possible. To this end, I have invited students (undergraduate and graduate) to come join me in the Keck Remote Room whenever I am using it.

The observing workshop for students at Lick Observatory is a terrific program and provides valuable experience. I hope all my students in the future will participate.

Alison Coil, UC Davis

Access to Keck and the future TMT were paramount in my decision to come to UC. **I had offers from other prestigious institutions, including Harvard, and I choose UC because of UCO facilities.** The superior telescope access and data quality at UC far outweighed what Harvard had to offer.

Data from Keck is the foundation of my research on galaxy evolution. Since arriving at UCSD, I use Keck data almost exclusively for all of my new research, and proposals I submit for data from other telescopes consist of supplementing my existing Keck data. I have been awarded a Sloan Foundation fellowship and an NSF CAREER grant, both as a result of my research with UCO facilities. I have also been awarded a Hellman Fellowship at UCSD and was a Kavli Frontier Fellow.

I **cannot overstate the crucial importance of UCO facilities, namely Keck, to my research and career. I would not be at UC without the UCO facilities.**

David Wittman, UC Davis

Keck is absolutely essential to my work. It was a huge plus in deciding to come here. It's also a huge plus for us when recruiting prospective grad students and hiring the best postdoc candidates.

David Williams, UCSC

UCO facilities have enabled me and my group to make unique contributions to the understanding of extragalactic, very high-energy gamma-ray sources, by virtue of our ability to obtain redshift information using both Lick and Keck. The work we have done on the redshifts of very high-energy gamma-ray sources has enhanced my stature and visibility, both within the VERITAS Collaboration with which I largely work and in the larger international community.

The loss of access to UCO facilities would have a significant negative impact on my research program and would have to be compensated somehow for me to consider moving to another institution. **Direct and frequent access to Lick Observatory plays a valuable role in the educational experience of my students.** State-of-the-art data from Keck that I am able to make available to them is another important part of their training.

Greg Aldering, LBL

My research focuses on cosmology with Type Ia supernovae. **For my work the value of Keck has been immeasurable; in equal measure with the Blanco 4-m at CTIO, the Keck telescope enabled the discovery of the accelerating expansion of the Universe. This discovery was awarded the Nobel Prize in Physics in 2011 - the only Nobel Prize ever awarded for a ground-based astronomy experiment.**

Keck in particular has been critical in the follow-on work - the Hubble Space Telescope and Keck telescope in tandem have led in progress in this field. There is no doubt that Keck is a key factor in maintaining Berkeley as the center of the supernova-cosmology universe. Keck alone, or success in obtaining HST time because of proven Keck access, are essential components to this research.

The Shane telescope on Mt. Hamilton has played a major role in my study of nearby supernovae. **It is also critical for training students and for testing out ideas that can lead to future projects at Keck or with HST.** UCO facilities have been essential in training students, not only to conduct their research while here, but also in making them competitive for the best postdoctoral and faculty positions once they graduate.

Since supernova work often involves numerous observing runs of just one night each spaced in time over a semester, it is very convenient to have remote access to both the Keck and Shane telescopes. Since supernova work often involves numerous observing runs of just one night each spaced in time over a semester, it is very convenient to have remote access to both the Keck and Shane telescopes.

Resultant awards/recognition: 2007 Gruber Prize as part of the Supernova Cosmology Project.

Rebecca Bernstein, UCSC

As an observational astronomer, the Keck telescopes are the primary tools of my scientific research. For the last 10 years, my primary research program has involved the development of a new technique for measuring abundances of distant galaxies. In order to make use of that new technique that I have spent 10 years developing, I need significant amounts of time on the largest

class of telescopes. **The best telescope and spectrograph on the planet for this work are the Keck telescopes and High Resolution Echelle Spectrograph (HiRES, installed 1992)** that was built for them by Steve Vogt (UCSC Professor). In the 20 years since this combination of telescope and spectrograph became available to the UC community, there has still not been a more effective or influential spectrograph built for high-resolution spectroscopy. It is not possible to obtain the kind of telescope access needed to develop a new technique like this and apply it successfully without private access to world-beating facilities like Keck and HiRES.

The remote observing rooms are an enormously efficient way to use the Keck Telescopes in terms of both money and time. They allow me to train students on Keck without spending thousands of dollars unnecessarily on travel. Also, there have been many observing runs that I would not have participated in because of conflicting commitments (like teaching) if it were not possible to participate remotely using the remote observing rooms. In these cases, I would have sent students or postdocs to observe for me, and I believe that in some cases the research and observing efficiency would have suffered.

I am also an instrumentalist --- I design and build instruments for large telescopes. My specialty is the optical designs for O/IR imaging systems and spectrographs. Because I consider it a part of my research program to design and build instruments, the peer group of other instrumentalists at UCO is critical to my professional activities and professional satisfaction on an ongoing basis. Access to the community resources and staff skills at UCO is critical to planning and executing this part of my research. Appropriate laboratory space to test, integrate, and assemble large instruments for the Keck telescopes (and potentially the future TMT telescopes) is critical to my research life.

I joined UCSC from UMichigan in Fall, 1997. Michigan is a 20% partner in the two Magellan 6.5m telescopes at Las Campanas Observatory in Chile and was a growing department with a thriving group of young faculty, many of whom are engaged in instrumentation for the Magellan telescopes and other facilities around the world. **I would never have considered joining UCSC if it were not the home of the University of California Observatories**. (At the time I moved, I had financial equivalent offers from UT Austin, UC Davis, a generous retention package from UM, and all four institutions made matching offers to my partner.) If UCO ceases to be an environment where I have peers who are also interested in instrumentation, if the community here ceases to be stimulating to instrumentalists, then this will cease to be an environment where I can conduct my research and I will need to consider opportunities.

I have received significant recognition and satisfaction from designing and building the Magellan telescope's echelle (MIKE), designing the Magellan telescope's IR echellette (FIRE), and designing the Dark Energy Camera for the 4m Blanco telescope at CTIO. I believe that if I stay at UCO, it is only a matter of time before I will have similar involvement in Keck instruments.

Graeme Smith, UCSC

Keck telescopes were essential to two joint NSF projects that I had with Bob Kraft. HIRES spectroscopy of globular cluster red giants was a vital component of these grant applications. Of my current and previous NSF proposals Lick 3-m Kast spectroscopy of globular cluster red giants was a major component of both proposals - the research program being the study of carbon abundance on the red giant branches of globular clusters. This is a task that the Kast spectrograph on the Lick 3-m is ideal for when stars brighter than V ~ 16 mag are the objects of choice. Thus UCO facilities, both Lick and Keck, have been the underpinning of all my successful NSF grant applications.

I came to UCSC/Lick Observatory prior to the coming online of the Keck 1 telescope. Although the future access to Keck was of some consideration in coming to UCSC, **my predominant reasons for coming to Lick Obs/UCSC was the pre-eminent place and reputation of Lick Observatory in the context of U.S. astronomy and the eminence of the astronomy faculty**

at UCSC. Put simply, the fact that I would be a Lick astronomer (by which I mean a pre-UCO era astronomer) was a HUGE factor in coming to UCSC.

Education: the Lick 3-m has been a huge factor in realizing my goals for the graduate students that I have supervised. My ideal is to give grad students a thorough grounding in the planning, design, and carrying out of a large multi-year observational program. I have been able to do this with my grad students, all three of whom used the Lick 3-m to obtain all or a major part of their PhD thesis data. For example, Laura Langland-Shula's entire PhD thesis on the spectroscopy of comets was a multi-year program that used the Lick 3-m exclusively and produced a major compendium of observational material for some two-dozen comments. The major result from Sarah Martell's thesis on carbon evolution among globular cluster red giants was obtained from a multi-year campaign with the Kast spectrograph on the Lick 3-m. Access to Lick has been crucial to my PhD students and I do not think they could have gotten the same observational grounding by basing their theses on much more limited amounts of Keck time.

Personally one of the most edifying things I do in public outreach is to lecture at the Lick summer visitor program. My lectures try in some small way to generate an appreciation for the rich history of Lick Observatory. If one were to take Lick away a major part of the outreach effort of the UC astronomical endeavor would be jeopardized. It has been an honor to work for an observatory with such a rich legacy. It is what has made my appointment at UCO/Lick truly special and unique.

The recent trends in NSF funding indicate that access of astronomers to 4-meter class telescopes (and smaller aperture telescopes) is going to become more institutionalized. The days of having general access of the entire US astronomical community appears to be coming to an end for northern facilities unfortunately. This means that maintaining the Lick 3-m for those astronomers in the UC community whose research programs use 3-4 meter class telescopes is essential - we will not be able to rely on access to telescopes such as the KPNO 4-m, the WIYN, the KPNO 2-m to do our 4-m class science if the Lick 3-m is shut down.

Please be aware that closing the Lick 3-m WILL affect even those UC astronomers that are solely Keck users and who don't use the 3-m. This is because a closure of the Lick 3-m, combined with the trends noted in the preceding paragraph, will likely cause those UC astronomers who do currently use the 3-m to base more of their observing projects on Keck out of necessity. Thus I think it can be argued that closure of the 3-m will affect the oversubscription of UC time on Keck and will impact even those astronomers who are Keck-only users. I think we need a more holistic appreciation of what a closure of the Lick 3-m would do to the dynamics of the UC astronomical community. There is an ecology here of sorts in which the closing of habitat to one community of species could have unforeseen effects on other species. Not to mention the fact that closure of the 3-m would specifically adversely affect some key species such as graduate students and postdocs - who are formally eligible to apply for Keck time. It would be a mistake to think that these species could piggyback on the shoulders of faculty for Keck time. Again the ecology needs to be considered!

Michael Fitzgerald, UCLA

Keck is absolutely essential for carrying out my research, in particular, the adaptive optics imaging capabilities. Lick Observatory has also been useful for feeding and vetting targets. The UCLA Infrared Laboratory is also essential for my work in astronomical instrumentation, as are collaborations with the other UCSC instrumentation facilities. My research in high-contrast imaging benefits directly from work of the UCSC Moore AO Laboratory.

Keck and the instrument labs are the main reason for my seeking to join UC, and figure critically in my decision to remain. More strongly, UC's involvement in TMT is essential for my long-term retention in UC.

UCO facilities also figure critically in the training of graduate students. Access to world-class observational facilities where students take an active part in data acquisition is essential to training observational astronomers.

I was a co-recipient of the AAAS Newcomb Cleveland prize, based on research carried out partly at Keck Observatory.

Ben Mazin, UCSB

I develop instruments for UVOIR telescopes and use them to take science data. UCO facilities are my research program. **The facilities are extremely important - without access to Keck I might not have come to UC.**

Lick has been a useful testbed for our MKID camera ARCONS, and we hope to bring this instrument to Keck to make some cutting edge discoveries.

Gabriela Canalizo, UC Riverside

UCO facilities are crucial for virtually every research project that I work on. Of the 40 refereed articles that I have published since I was hired at UCR, 35 have been primarily based on observations made with UCO facilities. The ONLY reason I applied for a faculty position at UCR was that the position provided access to UCO facilities. Further, the only reason I applied for a postdoc at LLNL (before I came to UCR) was that, at the time, it provided access to UCO facilities. **Simply stated, I owe the success of my research program to my access to UCO facilities.**

The facilities at Mt. Hamilton have been essential in mentoring and teaching undergraduates and young graduate students. We have been able to send our incoming graduate students to workshops at Mt. Hamilton to introduce them to observational astronomy. I have used the remote observing room along with the Shane 3-meter telescope and the Keck telescopes to teach both graduate and undergraduate students how to observe. I have used these remote facilities for **public outreach** at UCR. I have taken both graduate and undergraduate students on field trips to the IR lab at UCLA. UCO facilities have also been useful in providing opportunities for our grad students that they don't have in our own campus. For example, **one of my students completed a PhD thesis in instrumentation at the adaptive optics labs at UCSC.** UCR has used footage of Mt. Hamilton and the Keck Observatory for the Living the Promise outreach campaign. It is obvious that the astronomy facilities capture the attention and imagination of prospective students and donors alike.

Kevin Hurley, SSL Berkeley

Access to Keck on a ToO basis has been indispensible to me and to students working with Josh Bloom, in studying gamma ray burst optical counterparts.

UCO Facilities have played a small part in my decision to remain at Space Sciences Laboratory, but a much larger one in getting graduate students to work on these projects. **The education aspect has been the most important one - many students have had access to what is indisputably one of the world's best optical facilities.**

When I write NASA proposals, it helps considerably to be able to say that I have access to Keck.

Lars Bildsten, UCSB

As an astrophysical theorist, I rely on direct Keck usage only rarely. However, when it's critical (such as the recent need to confirm the first double white dwarf binary), it has proved

tremendously beneficial. **I am also part of the Palomar Transient Factory, which heavily relies on Keck for spectroscopy of newly found transients and targets.**

Keck (and TMT) are internationally competitive facilities that enable astrophysical research across a huge dynamic range. This allows us to attract and retain excellent faculty; both the direct users, but also those of us who primarily interact with observers.

David Jewitt, UCLA

I use the Keck telescopes to drive my research into the primitive bodies of the solar system. I didn't discover the Kuiper belt with Keck, but I use it and need it to determine physical properties of these and other faint solar system targets.

I would not have moved to UCLA in 2009 without Keck access. I will leave if my access is reduced or eliminated. Astronomy is all about data. The top-10 institutions all have their own telescopes. UC will plummet without UCO.

I use my observing activities as a magnet in classes (e.g. ESS 9) and public lectures and it always works. People love telescopes and astronomers using telescopes. Take a look at http://www.kavlifoundation.org/2012-kavli-prize-public-laureate-lectures#KP2012PLL for an example.

UCO is better than public observing facilities in several ways. A major one is that when using my own facilities, I am not held closely to a pre-arranged object list or plan of action. I can do what I want. This means that I can capitalize on the latest developments with minimal institutional interference, and therefore can do the best science.

Gary Chanan, UC Irvine

My research has been on the development of the Keck telescopes and now TMT. I used Lick Observatory in the early stages of my research on this subject. I could not have done any of this research without UCO facilities. I would not have come to UCI if it were not for the Keck Observatory. UCO facilities enabled me to develop knowledge and skills that made me useful as a consultant to MacDonald Observatory, Gran Telescopio Canarias, Southern Africa Large Telescope, Palomar Observatory, Jet Propulsion Lab, European Southern Observatory, and the James Webb Space Telescope.

All of my undergraduate researchers, graduate students, and postdocs used UCO facilities for their research. Three of these former group members are now JPL staff members, three more are TMT employees, and two others work in closely related fields.

Jason Prochaska, UCSC

[UCO facilities] are essential in that the majority of my research in observationally oriented and requires the larger aperture and high performance of the Keck Telescopes + instrumentation. While I do make use of other larger aperture telescopes outside of UCO, the impact on those is much less than that from UCO. The usage of the Lick 3m Shane has grown in importance over the past 3 years. I now consider it very much needed to promoting my research program.

My primary career goals have been to achieve tenure and remain at the forefront of astronomical research. My access to UCO facilities has been essential to accomplishing these goals. The access to UCO facilities (Keck, Lick, instrumentation) was critical to my coming to UC and to my remaining at UC. These facilities give me a terrific competitive advantage and enable me to pursue my primary research goals.

Alex Filippenko, UCB

UCO facilities have been used for a majority of the research I have done as a professional astronomer. Both Lick and Keck have been, and continue to be, essential to my research program and to achieving my career goal, which was to contribute substantially to our understanding of the Universe.

Lick Observatory provided a home for my robotic telescope, the Katzman Automatic Imaging Telescope, which for a decade conducted the world's most successful search for relatively nearby supernovae. It is still very active, though other groups have used our success as partial motivation for larger, wider-angle sky surveys. Without access to a nearby, convenient facility, this project (initiated after I received an NSF Presidential Young Investigator Award in 1989) would not have been possible. KAIT and the resulting data have been used in many ways, including refinement of the cosmological use of Type Ia supernovae.

Frequent access to the Lick 3-m Shane reflector allowed my group to spectroscopically classify most of the KAIT discoveries, as well as supernovae found elsewhere. We also monitored the spectral evolution of different types of supernovae, leading to the identification of new subtypes and providing major contributions to the development of Type Ia supernovae for cosmological uses.

I have done a large number of studies with the Keck telescopes. Most notably, I was a key member of both teams that discovered the accelerating expansion of the Universe, which was honored with the 2011 Nobel Prize in Physics to the team leaders. I obtained all of the Keck spectra, which were used to spectroscopically verify SN Ia candidates and determine their redshifts. **My research, done mostly with UCO facilities, has led to about 700 published papers, and I was the world's most highly cited astronomer in 10-year intervals ending in 2003, 2004, 2005, 2006, 2007, and 2008. I have received numerous prizes for this research, including a share of the Gruber Cosmology Prize and the reflected glory of the 2011 Nobel Prize in Physics, and I am an elected member of the National Academy of Sciences.**

UCO facilities were critical to my decision to join the UCB faculty -- and I had many juicy offers from other outstanding universities. At the time, we had only Lick Observatory, which was and still is crucial to my research. There was also the future promise of the Keck Observatory.

Maintaining access to Lick and Keck are very important considerations for my retention on the UCB faculty. I continue to get occasional expressions of interest from other excellent institutions, some of which now (or soon will) have access to competitive facilities.

I have had a great time showing select undergraduates from my large introductory astronomy course how real research is done by bringing them with me to Lick on observing runs. This kind of educational experience is quite rare at universities. Moreover, over the past quarter century nearly 150 undergraduates have participated in my research group, mostly through observations at Lick: they have helped identify new supernovae, and they have taken and analyzed data, obtaining invaluable hands-on training that has served them well in their careers.

In the past few years, **the remote observing room at UCB has greatly increased the opportunity for meaningful observational experiences among undergraduate students.** They can assist with observations without seriously compromising their coursework; each student can, for example, take half of the night, depending on when his/her classes are scheduled the next day. We don't have to worry about getting them to and from Lick Observatory, and having them miss classes. We have had undergraduate students take a lot of data with the Lick Nickel and Shane telescopes. The remote observing room also allows more undergraduates, graduate students, and postdocs to help with Keck observations, since we don't have to spend a lot of

money (and time) flying them out to Hawaii. The amount of effective mentorship of students has thus increased.

At the Lick Observatory Visitor's Center, I have had the opportunity to conduct significant **public outreach** by speaking once per year for the summer visitor's program, and on some other special occasions.

The Lick and Keck Observatories have been useful for my private fundraising efforts: I have taken various potential donors with me on observing runs, showing them how we obtain real data with the telescopes. They have been impressed with the facilities and in some cases have already donated substantial funds. I expect other such contributions in the future; it takes time to develop meaningful relationships with potential donors.

UC owns Lick Observatory, and the cost of running it is relatively low. It is a very important facility for a number of reasons.

1) It provides substantial, direct access to telescopes for undergraduate students, graduate students, and postdocs, so they can develop their observational skills.

2) Graduate students and postdocs can be PIs of Lick proposals, but not Keck proposals. They can conceive, propose for, execute, and complete their own projects.

3) Lick can be used for long-term, synoptic projects, such as monitoring supernovae, everberation mapping of active galactic nuclei, and detection of exoplanets.

4) Lick provides a useful testbed for new instruments. Adaptive optics, for example, was largely developed at Lick.

5) ***Much public outreach and education is done at Lick.*** *Although only a minority of UC faculty now use Lick Observatory, it is important to certain faculty and other researchers, for some or all of the above reasons. A useful comparison can be made with a single, specific Keck instrument: it is generally used by only a minority of UC faculty, yet we understand its value and contribution to our overall astronomical enterprise.*

Harland Epps, UCSC

I have used the UCO/Lick computing facilities to develop optical design software that is essential to my research in high-performance optical instrumentation for astronomy. I make use of assistance from members of the NICS and Scientific Computing staff at UCO/Lick on a daily basis. I have used and am currently using services from the UCO/Lick mechanical engineering and fabrication groups and especially the optical fabrication group to turn my designs into practical instrumentation for Lick and Keck. Examples include but are not limited to the Prime Focus Field Corrector and the Hamilton and Kast spectrographs at Lick; the LRIS, HIRES, DEIMOS, ESI and MOSFIRE spectrographs at Keck and aspheric lens and mirror profilometry, which was essential for making the Keck secondary mirrors and lenses for the aforementioned spectrographs, etc.

I served as an astronomy professor at UCLA for 24 years before coming to UCO/Lick. My primary reason for choosing the UCO/Lick Observatory environment was based on the critical mass of instrumentation technology facilities and the opportunities they provided for me to develop my career to a full extent that I had not been able to achieve at UCLA, or with various other groups such as Steward Observatory and Smithsonian Astrophysical Observatory where I had been extensively involved as a colleague.

The UCO/Lick facilities have made it possible for me to provide optical designs and to supervise the construction of a large fraction of the instruments that have been and are

being used over the past 2 decades at Lick and Keck by all of the UC astronomy groups Statewide. My work would have been impossible to achieve without those facilities. At present, I continue to use the UCO/Lick facilities to construct the all-important reimaging camera for the Keck Cosmic Web Imager (KCWI) in co-operation with colleagues at Caltech.

My special 100% Astronomer position at UCO/Lick has provided me with an opportunity to apply myself to the challenges that are presented by the quest to design the most powerful instrumentation on the Planet, on a schedule not limited by "standard" professorial duties. Although *not required* by the Astronomer job title description, I have enjoyed teaching and the supervision of PostDocs on a fairly extensive volunteer basis as time has permitted.

I am the most senior faculty member at UC Santa Cruz and probably University-wide, with nearly 49 years of recorded service. Over the span of my career, I've watched astronomy grow from a relatively tiny backwater science to a gigantic scientific enterprise, whose profound discoveries are known and appreciated worldwide by a large fraction of the international population. It is not an exaggeration to state boldly that UCO/Lick has served and continues to serve as the world leader in that pursuit. All that has been accomplished here was possible only because of the unique existence of the UCO/Lick organization.

Brad Hansen, UCLA

I have (most recently) used Keck to study transiting planets and the Nickel 1m to photometrically monitor transits. These facilities have proven to be central to the thesis work of the graduate student involved, and I believe they are key to attracting such excellent students to UC. My principal work is theoretical, so the facilities did not play a central part in my coming to UC. However, **their loss would make UC significantly less attractive because I have supervised excellent students who would not have come to our university without them.** Excellent theoretical research still requires an active and stimulating environment, which requires access to cutting edge observers and observations.

Michael Bolte, UCSC

Access to the Keck Telescopes has been absolutely critical to my research program. Access to the Lick facilities, primarily the 3-meter telescope has also played an important, though less critical role in my research. **Preferred access to the Keck telescopes is the single most important factor in my initial interest in a faculty position at UCSC and has remained a very important factor in me staying here in the face of multiple offers at other non-UC institutions.** Participation in leadership at the TMT, Keck and Lick observatories and participation in the instrumentation program have been important aspects of my career growth.

From the 2011 UCO External Review Report:

"Over the succeeding 125 years the formula for maintaining this leadership has been consistent: building world-class facilities which in turn attract outstanding faculty in astronomy and astrophysics to the UC campuses. Through the subsequent development of large telescopes on Mt. Hamilton, the construction of the Keck Observatory, and the establishment of major radio and millimeter-wave observatories the University stands at the cutting edge of astronomical facilities and instrumentation, and has helped build strong astronomy groups on eight UC campuses (as well as astronomers at Lawrence Livermore National Laboratory and Lawrence Berkeley National Laboratory). Through the Thirty Meter Telescope (TMT) project the University now aspires to extend and enhance its pre-eminent position in the coming decades.

A key element of this success has been the investment by the UC of nearly $20 million per year for the support of the Keck Observatory ($12M) and a Multi-campus Research Unit (MRU), the University of California Observatories (UCO; $8M)."

Kim Griest, UCSD

The HIRES instrument on Keck was the source of data for a recent PhD student of mine Jonathan Whitmore (currently postdoc at Swinburne U, Australia). We wrote a number of well-received papers based upon this HIRES data. Thus Keck was essential for my research and my promotion to professor step 8. Previous students of mine have used the Kecks, and having top observers here to talk with makes my research possible. The remote observing room is how we use Keck. It saves us enormous time and travel money.

I have been offered jobs at other top universities, but always decided to stay at UCSD. Even though I am mostly a theorist, **the level of observers attracted by UCO makes this a top-level research university.** Without UCO facilities, including TMT, UCSD's research ranking would drop very quickly and it would not be an attractive place to work for top scientists. **Without UCO facilities I almost certainly would not be at UCSD.**

The Kecks have been the top optical telescopes in the world for many years. This gives cache to any UC astrophysicist. For example, I was recently chosen as chair of the Astronomy and Astrophysics Advisory Committee, a FACA committee that advises Congress, the Administration, NASA, NSF, and the DoE on U.S. astronomy issues. **My association with the Keck telescopes gives me credibility when discussing the importance of upcoming research with colleagues across the country.** Scientists in other countries also give great respect (and are jealous of) scientists with Keck experience.

Even though I mostly work as a theorist **I ask all my students to train at Lick so they understand modern astronomical data. This makes them much more valuable as scientists and helps them get good jobs at top research institutions.**

Richard Puetter, UCSD

I have been using UCO facilities my entire career. I did my thesis research on the Shane 3m telescope (UCSD PhD in physics in 1980**). I have continued to use the Shane 3m throughout my career with 49 papers being published since the year 2000 that used Lick Data.** In summary, the **Shane 3m remains a workhorse instrument putting out top-flight science, and I hope to continue using this fine telescope.**

I am an IR astronomer and was a Co-PI in the construction of the LWS, one of Keck's first-light instruments. Because of its large aperture, the Keck is one of the finest telescopes for imaging at 10 microns and longer wavelengths where the telescope is diffraction limited. Only larger telescopes can provide higher resolution imaging. The strong motivation of obtaining the highest resolution images possible with Keck prompted me to go the next step, i.e., to develop the Pixon method for image reconstruction, allowing sub-diffraction imaging. **The Pixon method is currently the highest performance image reconstruction method and has been used in a number of different areas in astronomy,** including being the primary image processing technique in a number of astronomical satellites. In addition, **the Pixon method has been used in microscopy, where it has produced the highest resolution electron micrograph, resolving** individual atoms in nano-crystals. **It is also being used routinely in Siemens medical workstations to increase the sensitivity and resolution of nuclear medical imagery**. Under support by the US Missile Defense Agency, **the Pixon method was also adapted for real-time use for missile defense applications.**

Aaron Barth, UC Irvine

UCO facilities are absolutely essential to my research program and career. I've been able to lead large and substantial programs at Lick Observatory that I couldn't have carried out anywhere

else. **One of the great aspects of a facility like Lick, being fully owned and operated by UC, is that it enables UC faculty to embark on long-term, ambitious research programs that can't be done either at national observatories or at university-led observatories whose observing time is divided between a large number of stakeholders.** Keck Observatory is a magnet for attracting outstandingly talented students, postdocs, and new faculty to our program. The vast majority of my students' research has been done using Keck and Lick data.

Access to UCO facilities, and collaboration with the community of UC astronomers, are the main reasons that I wanted to join the UC faculty. **In terms of retention: at present I have no interest in even considering jobs outside the UC system, because the UC Observatories are so essential for my research.**

The summer visitor programs at Lick Observatory have been an absolutely outstanding way to connect with an audience of Californians who are excited about both the science done in UC and the historical aspects of Lick Observatory. Speaking to these audiences and meeting with visitors to Lick is always one of the high points of my summers.

UCO's investment in remote observing rooms has created a fantastic resource. The remote observing capability **saves money, saves time, lowers our carbon footprint by reducing travel, and allows us to train more students more thoroughly than we would be able to do otherwise.** UCO is still far ahead of a lot of the competition in providing this capability.

Sandra Faber, UCSC

At Lick, I used the IDS scanner on the 3 m for 13 years. It was seminal to my study of stellar populations in early-type galaxies. From those spectra, I developed the Lick spectral index system, which is the foundation of stellar line-strength measurements for galaxies.

The IDS spectra [obtained using the IDS scanner on the Shane 3-meter at Lick Observatory] provided the bulk of spectra for the Seven Samurai project, which was the first all-sky mapping of the local Hubble flow and discovered large-scale bulk motions, including the Great Attractor.

At Keck, David Koo and I used the LRIS and DEIMOS spectrographs to assemble first large sample of thousands of z ~ 1 galaxies in the DEEP2 and DEEP3 surveys.

The DEEP database and discoveries learned from it [using LRIS and DEIMOS at Keck Observatory] were critical to our designing a winning Hubble Multi-Cycle Treasury Proposal, which joined with Harry Ferguson's team to create the CANDELS survey, the definitive survey by Hubble of distant galaxies.

It is clear that at each stage UCO facilities were the springboard to each new step in my career.

In 1976 I had a job offer from the University of Maryland but stayed at UC because Maryland lacked an optical telescope.

In later years, access to Keck kept me from even thinking about jobs elsewhere, despite many offers.

Being a faculty member at UCO provided the additional thrill of being able to actually conceive, design, and execute improvements to the UCO telescopes. I am proudest of jumping early onto the Keck cause and providing the scientific case and of guarding the scientific integrity of Keck during construction as chair of the Keck Science Steering Committee. **The experience gained at Keck put me in a position to diagnose the famous optical flaw in the Hubble Space Telescope when it was launched.**

UCO facilities provide world-leading data in astronomy, a subject that entrances the public imagination. Astronomical leaders have the privilege of automatically being catapulted into the public eye. It has been extremely rewarding to have a second career in becoming a public spokesperson on behalf of astronomy and UC.

In retirement I will be exploring other ways in which astronomical discoveries can influence public policy. This further stage of my career will again build on my knowledge and experience as a UC astronomer.

Asantha Cooray, UC Irvine

Keck telescopes, especially the LGS+AO facility, have been useful for the follow-up programs involving selected sources from the Herschel Space Observatory. My group is one of the three key groups in US (with Caltech and Colorado) that was part of the US SPIRE instrument team on Herschel. We carry out the largest science program on Herschel, HerMES, taking over 1000 hours. Access to Keck have been crucial for the US science program with HerMES involving rare sources such as $z > 5$ massive dusty galaxies and lensed sub-mm galaxies.

Continued access to Keck will be part of the decision to remain on the faculty, if it comes to that in the future. Access to Keck has allowed me to expand my research group from primarily theoretical cosmology 10 years ago to now a combination of observational and experimental cosmology. The group includes post-doc researchers that primarily have observational astronomy experience and joined my group partly due to the availability of Keck. There are also undergrads and grad students who are benefiting primarily from Keck access.

Michael Cooper, UC Irvine

UCO facilities are essential to my research program. **The vast majority of my work is based on data collected at the Keck Observatory.** This includes current projects with the Hubble Space Telescope, with other national facilities (e.g. Gemini), and with international facilities (e.g. Plateau de Bure Interferometer) --- all of these efforts are largely driven by Keck observations. **UCO facilities also form the focus of nearly all of my proposals for research funds.** Finally, while this is my first year as a UC faculty member, **it is clear that UCO facilities have greatly aided me to this point in my career and that future UCO facilities (e.g. TMT) will play a central role in achieving my long-term career goals.**

UCO facilities (especially Keck and TMT) were one of the two main reasons (the other being the excellent faculty) that I decided to first bring a Hubble Fellowship to UC Irvine and second to recently accept a faculty position at UCI. The combination of UC's excellent faculty and resources within Astronomy & Astrophysics made UCI my preferred choice relative to other more lucrative (and perhaps prestigious) offers at both the postdoc and faculty level. Without UC's involvement in Keck, it would have been very unlikely for UCI to have successfully recruited me.

Donald Gavel, UCSC

LAO: used for testing and developing concepts for next generation AO systems including Multi-conjugate laser guide star AO instruments and high contrast planet-imaging instruments

Mt Hamilton: used Nickel telescope to test prototype MEMS-based AO system for visible wavelengths. Plans to use Shane telescope to install next generation near-IR to visible wavelength high-Strehl AO system, imager/spectrometer, and laser guide star.

These facilities are important to my career goals in my role as LAO director: advancing AO to be able to do forefront science, particularly long-exposure deep imaging of galaxies in dark fields, extending AO capability to complete coverage of near-IR to visible wavelength bands, and fully automating and simplifying the AO observation process to maximize on-sky science data collection efficiency.

I was recruited by Director Joe Miller (in 2002) with a "too hard to resist" offer to build a laboratory here in order to realize my design ideas, developed while working in the optics and lasers division at LLNL. This has allowed these ideas to be realized with actual instruments on actual telescopes at the Lick Observatory.

It has been an excellent opportunity to work with graduate students. The availability of UCO facilities, including the LAO and the Mt Hamilton telescopes, is sparking their interests and helping them to realize their research and training goals. **Several of the graduate students who have worked with me toward their PhD have both achieved significant results during their PhD research and are now strong contributors in the instrumentation field.**

Constance Rockosi, UCSC

Access to the Keck telescopes creates an entire new research direction for me. Before I came to UC, my only observational resource was the low-resolution spectroscopic data from the SDSS. **With Keck, I can observe stars selected from the SDSS at much higher resolution and measure element abundances, opening up a new set of scientific questions about chemical evolution of our Galaxy.** Because the SDSS catalog is relatively faint for high-resolution work, the synergy between the SDSS data and Keck is an almost unique opportunity. In addition, **a combined research program of AO science instrumentation at UCO with astronomical surveys of the Milky Way was the basis of my successful Packard Foundation proposal.**

The investment in technical facilities and professional staff and the core mission of UCO with astronomical instrumentation a research goal of the faculty were both a primary reason I choose UC over offers from other institutions. **The core technical staff has allowed me to expand my experience in ground based astronomical instrumentation while continuing an observational research program, a difficult thing to do at other institutions where it is necessary to bring in 100% funding for both a technical staff and a research group of students and postdocs.**

Claire Max, UCSC

Keck Telescopes: 1) Observing at Keck is a crucial element of my professional career, and of my students' training. 2) **I had the privilege of developing forefront new instrumentation for Keck (laser guide star adaptive optics); these instruments still lead the world in scientific productivity, citations, and technical performance.**

Mt Hamilton Telescopes: 1**) Provided a key opportunity to develop and test new prototype instrumentation. Facility-instrument versions (laser guide star adaptive optics) were later**

installed at Keck. 2) Observing at Mt. Hamilton provided data that formed the basis for future successful Keck observing proposals.

Moore Lab for Adaptive Optics: 1) Tested key components for the Gemini Planet Imager (MEMS deformable mirrors). 2) Worked with industry (Boston Micromachines Inc) to design and test new MEMS deformable mirrors, several of which are now commercial products. 3) Tested coronagraph concepts for detection of extrasolar planets. 4) Designed, built, and fielded the first open-loop MEMS-based adaptive optics system (Villages); proved key concepts for future Multi-Object Adaptive Optics systems. 5) was the experimental core for the Center for Adaptive Optics' research achievements.

I came to UCSC in order to design and build adaptive optics systems for Lick and Keck Observatories. I would not have come if these observatories hadn't been available, and I would not have stayed if the Lab for Adaptive Optics hadn't existed.

Using the Laboratory for Adaptive Optics, the AO system at Lick, and the AO systems at Keck, I have trained 14 graduate students and postdocs in how to do astronomy with adaptive optics systems. I have also trained 6 graduate students (with Don Gavel) in how to design and build AO systems, using the Lab for AO.

The Keck Observatory's telescopes, instrumentation, and staff are all world-leading. Their existence and excellence led luster to all of us astronomers at UC.

David Koo, UCSC

I am an observational astronomer with my main research program and career goals focused on undertaking the deepest optical/near-infrared imaging and spectroscopic surveys to study cosmology and the evolution of galaxies and AGNs. Keck, being the largest optical/near-IR telescope and having among the best instruments, has clearly been critical to stay at the forefront along this research path. I also like to try novel pioneering experiments. Here the **AO has been essential. Keck has provided the key asset that enabled me to be a major player/leader of DEEP, DEEP2, AEGIS, and CANDELS and almost all of my collaborations.**

The world-class UCO facilities made coming to and staying at UCSC a no-brainer decision for me. I did not respond to invitations to apply for more lucrative or higher titled positions elsewhere.

My research at Lick and Keck has provided the foundation for some of the content for my undergraduate classes as well as research opportunities for mentorship of undergrads through postdocs. This experience, as well as being an UCO faculty, has provided numerous opportunities to serve as a reviewer for both national and international organizations. Finally, having worked with UCO facilities provides an excellent and easy gateway for **public talks and development efforts.**

Provided opportunities to be engaged in instrumentation projects, including an early infrared camera at Lick, the Keck Atmospheric Dispersion Corrector, and the initiation through the NSF Center for Particle Astrophysics and design of DEIMOS.

UCO facilities also helped me to initiate the NSF Science and Technology proposals from UCSC that led to the Center for Adaptive Optics.

The excellence and prominence of UCO also brings world class theorists to all the UC campuses with astronomy and keeps them.

Tammy Smecker-Hane, UC Irvine

My research specialty is observational studies of stellar populations in nearby galaxies designed to measure the ages and chemical abundances of stars in the galaxies in order quantify the evolution of the galaxies and understand nucleosynthesis in stars and supernovae. My research has been nearly 100% observational in the last 20 years. Breaking it down, I would say 50% of my research has been conducted with the Keck Telescopes 30%, with the Hubble Space Telescope, 10% with Lick Observatory and 10% with US national ground-based observatories. Thus **access to the Keck Telescopes has been CRITICALLY important for my research and career success. Access to Lick Observatory has been critical for the development of my graduate students and postdocs, too.** Of my last 3 Ph D students, 1 used combined Lick and Keck observations, 1 solely used Keck observations, and 1 used observations at another US national observatory. My last 2 post-doctoral students routinely used Lick to pursue independent research projects that were key to developing their professional portfolio and attracting subsequent job offers.

I would say that 90% of the reason I joined this UC campus as a faculty member was because it afforded me access to Keck and Lick Observatories, which are absolutely critical to the type of research that I do.

My campus facilities, rather than UCO facilities, have allowed me to develop a vigorous Astronomy Outreach program and a very well known summer program for talented high school students, but the ONLY reason for that is proximity. We are not physically close to UCO facilities. Had I been at UCSC or Berkeley, which are close to UCO facilities, I likely would have used them for outreach.

The networking with colleagues that UCO provides -- the fact that our 10 campuses get together regularly for a yearly science meeting, for telescope proposal reviews, for colloquia -- is key to establishing connections, forming fruitful collaborations, helping design instruments for future research, and trading tips and tricks to maximize the performance of instruments and optimize data analysis. **We are much more successful as researchers and faculty because of the umbrella of UCO.**

Michael Gregg, LLNL

Both the Keck 10m and Lick 3m have played major roles in my research. Foremost, they make it possible to obtain high quality data, both imaging and spectroscopy. **The superb suite of optical spectrographs at Keck (LRIS, DEIMOS, HIRES, ESI) is a versatile set of instruments available for cutting edge research, and has played an essential part in my work on nearby galaxies and star clusters.**

And the Kast spectrograph on the Shane 3m telescope is one of the best spectrographs available. During our early work on the FIRST Survey, it was indispensable for our follow-up project on bright quasars and led to the discovery of the first radio-loud BAL and the discovery of further examples of the (until then) unique ``Iron LoBAL'' quasar. I continue to use Kast for bright object survey work.

A**ccess to UCO facilities has played an important part in obtaining both time with the Hubble Space Telescope and also funding from the National Science Foundation.** In grant and observing proposals, I invariably make a case that original or supporting observations can be carried out with UCO telescopes and instrumentation. **Because of the preferred access to UCO facilities that UC researchers enjoy, it is a much more powerful argument [in grant proposals] than promising to carry out observations with national observatory facilities. This gives UC researchers a significant advantage in proposing for funding and space-based observatory time.**

I recently declined a job at one of the national observatories; continued access to Keck and Lick did play a part in the decision to stay at U.C. Davis.

Malkan, Matthew, UCLA

As an observational extragalactic astronomer, there is no significant aspect of my research for my entire UCLA career that has not relied in some way on data I was able to obtain at Lick and Keck observatories. Admittedly NASA observatories also provided valuable data for many projects. In a small minority of the projects, additional key data came from other ground-based telescopes. But in the great majority of my research projects and publications, the full use of the NASA data could only be made when they were combined with the Lick and/or Keck observations. Take away all the data that those irreplaceable ground-based facilities have given me, and there would not be a lot of my scientific career left.

The decision to build Keck Observatory was the reason for my coming to UCLA, and turning down faculty offers at other prestigious research universities. Access to the Keck telescope played a significant role in my receiving a Presidential Young Investigator Award (in a year when only 50 were given out for all fields in the country.) The success of Keck I, and then Keck II, was the reason for I declined offers of interest to hire me away to other strong departments (such as the U of Arizona).

Observing at Keck and Lick observatories, and working with the data they produced, has generated unique educational opportunities for hundreds of students I've mentored, either one-on-one or in small groups (from high school, to college and graduate school, in the physical sciences, and in other areas of studies as well). **Many of these students have now gone on to highly successful careers as leaders in astrophysics, and other sciences.**

If we include the chance to explain the science of astronomy to the wider public through the mass media in a broad definition of 'outreach', then **UCO facilities played the staring role in almost all of my successful science advocacy efforts in newspapers, magazines, radio, film and TV.** Although the amount of science communicated in these efforts was of course far smaller than in the direct work with students, the total number of people who saw it has been in the millions.

Looking back at all the research I've been able to do with the Keck telescopes, I came up with the estimate that about 60% of it had some significant links to observations I made at Lick, which often laid some important groundwork.

Andrew Philips, UCSC

The UCO facilities I have been using for the last 10 years have primarily been the UCO Instrument Labs, to support instrument development and coatings research. **All aspects of the labs (engineering, mechanical fabrication, electronics and optics) have been essential to my research.**

The world-class observing facilities attracted me to UC, and becoming heavily involved in instrumentation development, they have definitely retained me here (UCO Instrument Labs & UCLA OIR Instrument Lab).

My career goals shifted from basic research to instrumentation development, and this has become the primary thrust of my research at UC. I have been able to mentor students interested in instrumentation. My work has certainly provided support/service to the UC astronomical community.

Geoff Marcy, UC Berkeley

I have used the Lick Observatory 3-meter "Shane" telescope extensively to search for planets around other stars. With this telescope my research group was fortunate to make historic discoveries. We discovered the first system of planets ever found around another star, Upsilon Andromedae, and its three planets. **We also found 70 of the first 100 "exoplanets" ever discovered.** We also discovered planets that revealed unexpected properties including elongated, elliptical orbits and close-in "hot" jupiters. We also found orbital resonances among the multiple planets orbiting other stars. **Without the Lick Observatory 3-meter telescope, operated by UCO, these historic discoveries would not have been possible.**

In 2002, I secured $6.4M for a new telescope, called the "Automated Planet Finder" (APF) to search for planets around other stars. I sent the funds to the UCO shops at Santa Cruz with the agreement that they would build the telescope "on the fast track", i.e. within a few years. During the ensuing decade, progress was slow, but the UCO shops asked for more funds. I sent an additional $300K of my family personal money (that my wife isn't happy about), and I identified yet another source of funds who contributed $650K. Now, in 2013, eleven years later, the UCO shops are close to finishing the APF telescope. It may be finished this year! It was disappointing that I've sent 7.4 million dollars to the UCO shops over a decade ago with no functioning telescope yet. But, it's almost finished!

My research continues to use the Lick Observatory 3-m telescope is marvelous ways, thanks to the excellent instruments and maintenance by the UCO shops. We use the 3-meter telescope to confirm the planets discovered by the space-borne "Kepler" telescope, with which we are discovering Earth-size planets.

I came to San Francisco State University because I hoped to use the Lick Observatory 3-m telescope. That 3-m telescope drew me to California higher education.

I owe my success to the Lick Observatory 3-meter telescope. The discoveries my research group made there launched my career. I am forever indebted to the Lick Observatory 3-meter telescope and to UCO for building the great instruments that it has.

UCO built the HIRES spectrometer in the 1990's, which has dramatically helped our search for exoplanets.6

James Bullock, UCLA

Though I am primarily a theorist, Keck has been quite important in my research program, enabling us to obtain observations to directly test predictions for dark matter structure -- observations that would have been impossible with any other facility.

UCO facilities in general factored heavily in my coming to UC. **As a theorist, I recognize that top-tier observational facilities attract the best observational astronomers in the world. I want to be in a department with these excellent observers and to take advantage of the theory-observer synergy that is so important in our field.**

Our access to Keck and other facilities also **helps us to attract great students and (importantly) independently supported postdocs, who bring their prestigious fellowships here partly because of the access we have.** I have been approached many times about leaving UC, but so few places offer caliber of facilities (and associated people those facilities attract) that I have chosen to stay put every time.

I recently supervised a PhD thesis of a student who wanted to do pure observational work, and my access to Keck allowed me to do this. This student (Erik Tollerud) ended up being the best student I have worked with in my career, and he ended up getting a Hubble Fellowship based on

the Keck-DEIMOS observational work he did here. He is well on track to be a successful, impactful scientist -- all because of the facility access we had here.

We recently hired a new faculty member who had competing offers, many of which came with start-up offers much higher (more than a factor of 2 higher) than our campus could afford during these lean times. In the end, he accepted our lower offer because he knew that he would have access to Keck and other UCO facilities (the competing offer would have allowed him to buy into telescope access elsewhere). **UCO facilities offer a huge value-added component to our department, allowing us to attract highly-sought after faculty candidates without the huge outlays of startup required in other fields of science.**

* UCO facilities enable top-tier science
* They attract high-caliber, highly-visible faculty
* Our best faculty will simply leave if we don't stay at the cutting edge of facility access, and this will result in a chain reaction. The theorists will leave if their best observational colleagues leave.
* These facilities enable us to attract great students, free national postdocs, and to bring in grant money
* Shared UCO facilities enable individual departments to bring in excellent hires with minimal startup costs.

Renate Kupke, UCSC

I have worked primarily in the UCSC Moore Adaptive Optics Laboratory since 2004. I have supported laboratory research projects, including the Mulit-conjugate adaptive optics testbed, and carried out research on pyramid wavefront sensing. We have also done research and measurements pertinent to both the Keck and TMT adaptive optics systems. **The Adaptive Optics Laboratory is highly specialized, and offers a unique environment for research in adaptive optics, with tools and expertise unlike any other institution in which I have worked.**

The UCSC Instruments Lab has provided vital support in the building of the Shane AO upgraded adaptive optics system for the Lick observatory 3-meter telescope. I have also participated in characterization of the TMT segment support actuators with support from the instrument lab.

The UCSC Laboratory for Adaptive Optics is the primary reason for my coming to UC and remaining as staff.

I have had the pleasure of mentoring several (seven) graduate students and two undergraduate summer interns through the UCSC Moore adaptive optics laboratory. **The laboratory enables hands-on experience in the specialized optics and electronics required for modern adaptive optics systems. This combination of disciplines is required for anyone wishing to pursue a career in adaptive optics.**

The telescopes on Mt. Hamilton allow our instrumentation oriented graduate students a unique hands-on experience in building astronomical instrumentation, especially adaptive optics systems. This is a rare opportunity in observational astronomy, which has become dominated by 8-10 meter telescopes and much larger (both in budget and manpower) instrument projects. I think the **hands-on experience produces instrumentation professionals with a much greater understanding of the process of instrument building, and provides the future technological leaders in our field.**

Brian Siana, UC Riverside

The Keck telescopes are essential for my research goals of studying the early universe. The Keck observatory is one of the two primary facilities that I use (the other is the Hubble Space Telescope). **Hubble is useful for finding the galaxies, Keck is *critical* for understanding their physical properties**: star formation rates, velocity and covering fraction of outflows, metallicities, ages, etc.

Most importantly, initial investigations with Keck have been used to obtain data and money from the Hubble Space Telescope, resulting in ~$600k in funds over the last four years.

I simply would not have considered UC Riverside if it did not have access to the Keck Observatory and was not a founding member in the Thirty Meter Telescope.

The Keck observatory is enormously important in training the next generation of astronomers on state-of-the-art instrumentation. Furthermore, the high profile research has resulted in a large number of requests for public talks.

Elinor Gates, UCSC

UCO facilities, particularly Lick Observatory, the engineering shops at UCSC and the LAO, are essential to my research on quasar host galaxies, my collaboration with Dr. Barth on everberation mapping, with Dr. Marchis on commissioning the FIRST instrument, and the design and construction of the new Shane AO system.

My career goals have always been varied, including working with and designing new high tech instrumentation as well as doing public outreach and education in astronomy. Lick Observatory's instruments and telescopes, engineering support from UCSC, and the Lick public programs at the visitor's center help me fulfill my goals.

The laser guide star adaptive optics system on the 3-m telescope and the opportunity to use it and assist with the design of the next generation of instruments is why I initially came to UC. **The establishment of both the LAO and CfAO, new cutting-edge instruments for the telescopes, as well as the opportunities to collaborate with faculty at all campuses are the reasons I remain here.**

The opportunities to do **public education and outreach** are extensive as part of my career at UCO. I help plan the public summer programs at Lick Observatory and design new outreach opportunities, such as the Lick Observatory Teacher's Institute. I also host tours of the facility for college classes and other groups as well as train volunteers to assist with all our public programs. My goals for teaching are also satisfied by the planning and teaching of the graduate student Observational Astronomy Workshop. Public education, both in California and beyond, is enhanced by the film crews that I have hosted that create documentaries about astronomy and the research done at Lick that are filmed at Mt. Hamilton.

The accessibility of the Mt. Hamilton facilities to the public and UC community for education and research at all levels is unparalleled. The ability to do hands-on observing training for undergraduate and graduate students with a large variety of instruments, or host talks for the general public, or try new types of instrumentation on the Shane and Nickel telescopes, in one facility is really remarkable and I'm often participating in any of these listed activities for a breadth of experience that I don't think I could have gotten anywhere else.

The accessibility of Lick Observatory's telescopes to researchers and students throughout UC is enhanced with the remote operations capabilities. The Nickel telescope, in particular,

can be used by undergraduates from their home campus to get experience with modern telescopes and instruments that is hard to achieve anywhere else. **Having a shared UC astronomical facility, e.g. Lick Observatory on Mount Hamilton, gives students and researchers access to better telescopes and instruments than would otherwise be possible and opens up modes of observation, such as time domain astronomy, that are simply not possible with the national telescopes or the largest telescopes** (e.g. Keck).

David Tytler, UCSD

In 1990 and 2000s made extensive use of Keck HIRES and Lick 3m Kast spectrograph. However progress been painfully slow, especially recently, so on balance I no longer think these facilities benefited my career goals.

Keck was a key factor in deciding to come to UC. Importance has declined over time as number of UC users and Keck instruments increased leading to less time available.

Delighted with the remote observing capability that I have used with great success for teaching. Have used data from Keck to mentor many undergraduates and graduate students.

Naveen Reddy, UC Riverside

Keck is essential to my research program. My research is focused on imaging and spectroscopic studies of the physical characteristics of high-redshift galaxies (z>2). Observing such galaxies requires the large aperture and instrumentation capabilities of Keck, particularly for the rest-frame far UV and near-IR spectroscopic properties. The importance of telescopes like Keck to carry out my research is one of the main reasons I accepted a faculty job at UC Riverside.

As noted above, UCR's access to Keck was one of the top reasons (if not the top reason) as to why I came to UCR.

My access to Keck has allowed me to do research in a cutting-edge area of astrophysics, and the results of the research have given me opportunities to give talks at various astronomical institutions, as well as public talks (e.g., to the Riverside Astronomical Society). **The access to Keck is very important for us in attracting some of the best graduate students and postdocs in the world. For example, I am supervising two prize fellows (a CGE fellow, and a Swiss National Science Foundation Fellow), who have come to UCR in part because of the research that I do as well as the access to Keck.**

As mentioned above, aside from the necessity of Keck to my research, the access to Keck has enabled us to attract some of the top graduate students and postdocs. **It also gives us, as faculty, and the students, a large amount of visibility throughout the international astronomical community.**

Jean Turner, UCLA

I work on the youngest star-forming regions in galaxies that are undetectable at visual wavelengths due to high extinctions of tens of magnitudes or more. **Keck instruments, including the former Long Wavelength Spectrometer, LWS, and NIRSPEC, have been essential to my characterization of the youngest star-forming regions.** The detection of mid-infrared continuum from NGC 5253 established it as a young, embedded, and optically thick HII region, the first such known and likely the youngest known super star cluster. That was not possible using radio continuum measurements alone. The Brackett line spectra from this source indicated that the nebula is gravitationally bound, a new concept at the time but now widely accepted as an early stage in HII region development. The early states of these clusters are crucial to their subsequent development and can only be studied at infrared and

millimeter/submillimeter wavelengths. OSIRIS data on the central parts of the spiral galaxy NGC 6946 has led to the idea of gas-assisted cluster migration in galactic centers (submitted, currently in revision.)

I trained as a millimeter astronomer studying large star-forming regions, both Galactic and extragalactic. However I have been identified with discoveries about the properties of young super star clusters obtained using the infrared instruments on Keck as much as the radio continuum work I began with. The ability to work in the near-infrared, especially to reach Brackett alpha at 4 microns, is incredibly important for these studies of high extinction regions. The Keck infrared capability, particularly the high spectral resolution of NIRSPEC, has been very important to this work and will be absolutely crucial in the era of ALMA, which has very high spatial and spectral resolution. Keck can come close to matching these in the infrared with NIRSPEC.

Keck was still in the planning stage when I came, but the reason I came to UCLA was its long-wavelength orientation, and that has only intensified since then. I have had a number of opportunities to leave in the last decade. Keck access has not been the only reason to stay, but it plays an important role both in terms of obtaining useful infrared data and in the richness of the research going on in our department. If there hadn't been Keck I almost certainly would not be here now.

An aspect of teaching that is very important to me is the broadening of the field to include underrepresented minorities, people who do not have easy access to higher education or even to the idea of advanced degrees. This used to be mostly women but now the underrepresented groups among young people are Latino or African-American, Native American or Pacific Islander. Working on Keck data has been an exciting way for these undergraduate and graduate students to get involved in the field at a very early stage. I have had a number of students from underrepresented groups, including female, Latino, Latino-Persian, Korean, and African-American students, most of whom have worked on Keck data, either on summer projects or as independent study projects. All of these students have gone on to graduate school in physics, astrophysics, or engineering. My current undergraduate student is African-American, and he is working on Keck data from NIRSPEC. His work has revealed a genius for analysis that will be instrumental in his getting to graduate school. Once these students get to graduate school, they are on the way to becoming role models for future generations of students like themselves. **This broadens the pool of scientists, good for science and good for a diverse state like California.**

It is obvious but bears mentioning that training Ph.D. scientists is good for California and for its economy. Among my former students are engineers, managers, faculty, and mission scientists. Without the facilities of UCO we would not be nearly as good at training students in cutting-edge science.

Imke de Pater, UC Berkeley

I have only used Keck for my research.

Keck has been extremely important during my career as full professor at UC Berkeley. My IR career started with the impact of comet Shoemaker-Levy 9 in 1994. With the advent of AO, I was one of the first scientists who exploited this for Solar System Science. This was a turning point of my career from a pure radio astronomer to someone using both radio and OIR techniques.

I have used research results in education, public outreach, etc. Have had a fair number of press releases, and newsworthy items over the years.

Keck AO is unique in that Keck is the only telescope where one can use AO on large (3-4") objects and get to the diffraction limit of the telescope.

James Larkin, UCLA

UCO facilities, in particular Keck and the development of TMT are essential to my research and my career. Keck, with leadership from UC has maintained a consistent lead in capabilities over the competing 8-meter telescopes and has developed one of the most powerful communities of astronomers in the World. My research depends entirely on angular resolution and the adaptive optics systems. The Keck AO system, the development of the laser system and our own contribution of the OSIRIS instrument have given us a unique ability to dissect galaxies in the Early Universe. While two competing instruments (which were behind in terms of high resolution spectroscopy) exist, they do not achieve the same spatial resolution, and for a long time could not even observe the same galaxies. The future of this and much other high-resolution science hinge crucially on the development of TMT. The Europeans are moving forward with their own giant telescope, and the TMT community is coming together. UC hesitation and internal disputes are souring this collaboration and is threatening the future of UC astronomy. If TMT is not supported by UC, I will likely consider leaving the UC community.

The only reason that I'm at UCLA is the presence of the Keck Telescope. I had four competing offers including one at higher salary from Stanford when I accepted my current professorship at UCLA. This was both because of the opportunity to build instruments for Keck, but more importantly the access to the World's most powerful optical/infrared telescope. UC has continued to lead with the development of TMT. The continued participation in TMT is essential to my future research and instrumentation programs. Four years ago I led the search that resulted in the hire of Professor Mike Fitzgerald at UCLA. His primary attractions to UCLA was access to Keck, the ability to collaborate with the Infrared lab, and the ability to make innovative instruments for UCO facilities including Lick, Keck and TMT.

Everyone of my six graduate student PhD's have observed at Lick and Keck observatory and have used at least 75% of the available instruments at some point. This is crucial training and has allowed my two most recent graduate students win prize postdoctoral fellowships and in one case a recent professorship. I have given many public talks including those in K-12 institutions. All of those presentations involve my research and instrument development within the UCO facilities. I've hosted 6 REU students all of whom have depending on UCO facilities.

The time allocation process, service on the Keck and TMT science steering committees, optical design facilities, and the establishment of the NSF center for Adaptive Optics have all been crucial for my career.

The current internal struggles between the office of the President and the UCO administration is straining on everyone and jeopardizing the UC participation in the TMT. UCO is far more than a multicampus research organization and represents an almost unique assembly of astronomers. We've been through several years of reviews and external reports. Problems have been identified, but the overall health and vigor of UCO and UC astronomy in general has been praised. Yet, again there is an assault being made on the institution, with little justification that I can ascertain. This is all a huge distraction in the middle of the most crucial phase of TMT collaboration. If the TMT project falls through, UC leadership in the next decade will decay.

Bradford Holden, UCSC

My research focuses on two fields, the scaling relations of early-type galaxies and the properties of the first galaxies in the history of the universe. Both of these require spectroscopic measurements of redshifts, velocity dispersions, and other properties such as the

strength of emission lines as an estimate of star-formation rates. The data are often long exposures, > 6 hours, with the largest available telescopes. **The Keck observatory is critical for this, as it provides a combination of powerful instruments with an efficient, well-run observatory.**

Without Keck and the attached instruments, I would be required to use the Gemini observatories or, through collaborators, obtain access to VLT. Both of these options can be done at other institutions. Many of these institutions have not gone through the brutal funding cuts that UC has over the last 5 years.

The attraction of working with both Mt. Hamilton and Keck observatory attract high quality students and prize fellowship winning post-doctoral scientists. Because of the exciting of the data and facilities, I have been able to work with an advanced undergraduate (now working to become a science teacher in the local school system), multiple graduate students and a series of prize fellows.

The attraction of these facilities also means that I have given **public presentations** to local astronomy clubs and to undergraduate focused local universities.

The ability to try new techniques or new trial observations is important for both my personal research career but also for the community as a whole. National observatories do not have these luxuries, as they most serve a large community. Being able to use, for example, twilight time at Keck or time on the Shane 3m, to try new observations or new approaches to acquiring data, not to mention larger experimental work such as AO, is important to furthering observational astronomy.

UCO has achieved something unique in that we have an integrated observatory across multiple institutions. Most places, such as OCIW, NOAO or CalTech, have all of the individuals involved at one location with the exception of the day-to-day technical staff that resides at the telescope. UCO has integrated two different campuses into regular observatory functions and often has participation from other campuses, especially UCB. The flexibility required to achieve this means that we can easily work with CalTech on both Keck and the TMT, and bodes well for working with other TMT partners.

Michael Jura, UCLA

The Keck/HIRES facility has been essential to our program to study externally-polluted white dwarfs to measure the elemental compositions of extrasolar planetesimals. It is realistic to argue that we have been at the forefront in this specialized area that is a uniquely powerful tool for studying the history and evolution of extrasolar rocky planets. During the past few years, we have found:

- To date, when well studied, extrasolar planetesimals resemble bulk Earth. That is, more than 85% of their mass is composed of four major elements: oxygen, magnesium, silicon and iron.
- Despite being cosmically abundant, carbon is less than 1% of the mass of extrasolar planetesimals; bulk Earth also is very deficient in carbon relative to a solar composition.
- Bulk Earth is \dry" in the sense that it is less than 1% water. Similarly, at least in aggregate, extrasolar planetesimals are equally dry.

Since July 1, 2010, this program has received the following external recognition:

- Jura gave an invited review at IAU Symposium No. 293 in Beijing, China, “Formation, Detection and Characterization of Extrasolar Habitable Planets".
- Jura has been invited to give a plenary talk at the 221st AAS meeting in Long Beach on

Wednesday, January 9, 2013: “The Elemental Compositions of Extrasolar Planetesimals from Spectroscopy of Polluted White Dwarfs".

- Jura has been invited to write an article for the 2013 volume of Annual Reviews of Earth and Planetary Physics.

Since January 1, 2010, significant grants have been received from the National Science Foundation and the Space Telescope Science Institute. Jura was awarded $241,000 from the NSF for the three-year period September 1, 2012 - August 31, 2015 for these studies. This was a particularly competitive year for NSF grants.

Jura also was awarded a cycle 18 HST grant for $99k. Keck data were essential to the success of this proposal where we aimed to acquire ultraviolet spectra of white dwarfs for which we already had optical spectra.

Additionally, Jura was awarded cycles 7 and 8 Spitzer grants to search for dust disks orbiting white dwarfs. These small grants of $5k each are related to our research program.

From January 1, 2010, a total of $350k has been awarded to our research program.

Shoko Sakai, UCLA

Spectroscopic data from the 3m have been essential in completing some of the projects. I have used KAST to obtain spectroscopic data for nearby galaxies to measure velocities and metallicity distributions.

Garth Illingworth, UCSC

Modern research programs invariably require the use of a number of facilities. My research on distant galaxies is especially synergistic with using HST, Keck and Spitzer to help us understand the nature of galaxies in the first billion years. The opportunity to use remarkable space facilities for imaging (HST, Spitzer) along with the extremely capable spectrographs on Keck (DEIMOS, LRIS, NIRSPEC, and for the future the remarkable new MOSFIRE) has enabled us to remain competitive (and to even be in a leadership position) with the very best groups working in this area worldwide. **Keck spectroscopy is crucial for us.**

I came to UC and UCO/Lick in the late 1980's because of the international stature and the opportunities at UCO/Lick. The opportunity to be deeply involved in the development and construction of a whole new generation of large telescopes with a never-before used technology was exciting. The decade from ~1988 through to 2000 was a remarkable period. The two Keck telescopes were exciting developments and I was deeply involved with the telescope and instrument development, and with the management of the instrument development (DEIMOS conceptual development; Keck Segment Acceptance Committee; Keck Science Steering Committee role as "instrument project manager"). In addition to the remarkable opportunity to be involved with a new project utilizing cutting edge technology (Kecks), **the scientific opportunities from Keck and its new generation instruments were a key factor in my interest in UC and UCO. The Kecks have also greatly enhanced UC's ability to bring in the best young people across the system, and to enhance the attractiveness of UC for postdocs and graduate students.**

I am very supportive of value of outreach. **Our facilities and research are largely publicly-funded and we have a broad responsibility to ensure that the public shares in the excitement of discoveries, and that we use this excitement to enhance interest in science education and to help strengthen support for science and technology education and R&D both within California and nationwide.** The enthusiasm of graduate students and undergraduates for carrying out research programs using data from a cutting edge facility, namely "the world's best optical telescope", has been very valuable for UC's visibility as a leading

educational/research center. The excitement engendered by being involved at the forefront is infectious!

Having these facilities has been a driver for doing high-technology projects that will keep them at the forefront. There are about 15 8-m class telescopes worldwide. Each one wants to be the "best" with the most powerful instruments so that they can be at the cutting edge of research for their users. **This competitive environment has kept us focused on taking advantage of the latest technologies at UCO and across UC astronomy (AO, IR instruments, optical instruments).** We are driven to conceptualize new instruments that will keep Keck ahead of the competition and these technologies have strengthened our whole program.

The facilities also make us competitive for the best technology focused physicists and astronomers. UCO is attractive to these people because of its facilities and because of the environment at an Observatory that rewards technologists and gives them an environment that is supportive of the focus on technology (which astronomy departments generally do very poorly).

Having a strong observatory along with strong academic departments within a University environment has proven to be remarkably powerful -- WHEN IT IS DONE CORRECTLY. ***UCO/UC astronomy combined got a remarkably strong review from the External Review Committee.*** *I suspect that not all university-based observatories would have got the same strong statements. In fact, I am sure that they would not have done so. While organizations like Steward Observatory or McDonald Observatory have been centers with some unique capabilities, the breadth and depth of their achievements would not, I strongly suspect, have resulted in the same strongly positive support. The likelihood that UCO/UC astronomy would get such a positive report from a similar external review in 5 years is very unlikely if the VP Beckwith model of a dramatically cut and dispersed observatory is implemented.*

Steven Furlanetto, UCLA

Even though I do not use UCO Facilities, they were a large factor in my decision to move to UCLA. **As a theorist, I thrive when surrounded by observers doing the forefront research that Keck and the other UCO facilities enable. It is a network effect that reaches beyond the users themselves and attracts people like me to the program.**

Dan Lubin, UCSD

Lick Observatory on Mount Hamilton (including the 3m, Nickel, and CAT telescopes) is absolutely essential to my research program, and is vital toward realizing my career goals. My research involves study of variability in solar-type stars as it relates to global climate change on Earth. This is a topic in which few researchers are working rigorously, and for which Lick Observatory has excellent facilities.

I would have much less incentive to remain at UC if Lick Observatory were not available. **These facilities, dedicated primarily to UC researchers, are key to keeping UC as a first-rate institution for physics and astronomy.**

The program I have just started, related to terrestrial climate change, should have significant societal impact beyond astrophysical research, in that it will help clarify the role of the Sun as compared with the known role of industrial greenhouse gas emissions in changing climate throughout the rest of the century. There has been much misinformation fed to the public from the climate change "skeptic" organizations, and rigorous science is necessary to help clarify the issue for the public.

The Mount Hamilton Visitor's Center is an excellent venue for public outreach and communication of science. I am currently working on material for public display there. **The Mount Hamilton staff is a very highly talented and dedicated team of professionals.**

Bahram Mobasher, UC Riverside

UCO facilities (Keck) is absolutely essential for my research. I am also involved with TMT instrumentation and this would play a big role in my future research.

Keck Telescopes were a very important part of me moving to UC.

UCO facilities have been extremely important for my students and myself. This is true in cases of Keck, Lick, and the Adaptive Optics center.

We need more communication between UCO and UC campuses. We need more transparency about the UCO.

James Graham, UC Berkeley

I am project scientist for the Gemini Planet Image (GPI). Together with PI Bruce Macintosh (LLNL), this instrument (in various guises) has been my focus for nearly a decade. The GPI hardware was designed and fabricated by seven international partners, including two UC organizations---LLNL (AO: PI-David Palmer) and UCLA (integral field spectrograph: PI-James Larkin), and the test and integration facility for GPI is located at UCO. Although the hardware for GPI was fabricated off-site, the approximately two-year test and integration phase has been the most crucial phase of the project for this unique instrument. Although GPI is funded externally, the pool of technically excellent UCO personnel (including Don Gavel & Darren Dillon) is unique and is not replicated at any individual UC campus (or elsewhere for that matter.)

I am also a regular user of Keck, especially the AO system on Keck 2 and the integral field spectrograph OSIRIS built at UCLA. The research of my most recent graduate student (Nicholas McConnell; ""Black Hole Masses in Nearby Brightest Cluster Galaxies"", UCB PhD 2012) was only possible through the combination of these two unique facilities. In a parallel project we tried to obtain similar observations with Gemini/NIFS. Although in principal this should have been feasible, we never were able to achieve useful results. It is worth noting this experiment had been previously attempted (unsuccessfully) by astronomers who had been granted NOAO Keck time. I credit our success to being members of the UCO family, which allowed us to work closely with the observatory to design our observing strategy and to contribute to the on-going AO upgrade program at Keck. "

Paul Kalas, UC Berkeley

As an observational astronomer, the telescopes listed above are essential, as well as the UCLA IR and UCSC instrument labs. They define a career as a UC astronomer.

UCO facilities (the adaptive optics programs at Lick and Keck) were pivotal in coming to UC.

Numerous doctoral students received their fundamental training in observational astronomy at Lick and Keck, which cannot be adequately substituted by other opportunities at other observatories.

New instrumentation is critical over 5 year timescales and fundamental to staying competitive.

Mauna Kea is fundamentally limited in terms of new telescopes that can be built. Therefore over decade timescales, Mt. Hamilton is the key opportunity for innovative and new observatories.

David Lai, UCSD

UCO facilities are vital to my research program. My work centers on the detailed chemical abundances of halo stars to understand both the nature of the earliest stars and the potential formation mechanism of the Milky Way halo. In particular, this requires going after very faint stars to obtain relatively high-resolution spectra. These two constraints make facilities such as the ones provided by Keck (in particular the HIRES and ESI instruments, and to a lesser extent LRIS for this particular research) vital. This is because spectroscopy is inherently inefficient, so you need a combination of very large collecting area and very good instruments, both of which are provided by Keck. Very few facilities provide this capability, with UCO being one of them.

These facilities are very important. Very few institutions provide reasonable access to large telescope facilities like Keck with truly world-class instruments. Without facilities like UCO provides, it would be extremely difficult or impossible to pursue some of my research goals, such as finding and studying the earliest stars.

In terms of outreach, in the past I have been involved in UC based summer programs for high school students. We were able to employ data taken directly with the Nickel telescope for some of the projects undertaken. This proved invaluable in giving the students a hands-on feel for the actual scientific discovery process.

Robert Antonucci, UCSB

At least 50% of my research depends on UCO facilities.

In the past few years, we have used Keck Observatory for many really cutting edge discoveries. We have used the technique of spectropolarimetry to reveal spectral feature from the "Central Engine" of quasars - this is the first time any spectral features have ever been seen from the "prime mover," and it represents a breakthrough - our final results appeared in Nature in 2008. My UCSB colleague Omer Blaes was part of this project, as well as my former postdoc Makoto Kishimoto.

I participated in early "adaptive optics" observations with Claire Max (UCS) and Gabriella Canalizo (UCR). In this method one uses a laser shot backwards through the telescope to make an artificial "guide star" in the sky - allowing us to remove the blurring effects of Earth's atmosphere is come cases. For a given wavelength, the sharpness of our data was 4x better than the Hubble Space Telescope.

We have made even sharper (though primitive) images by combining the signals from both Keck telescopes at once and mathematically processing (by Fourier transforms) the combined signals in real time. I claim that we are the leading group in the world in this area, in the field of quasar-like objects.

Most of my graduate students' theses were based at least in part on data from UC astronomical facilities.

I'm VERY proud of my astrophysics colleagues, both at UCSB and throughout the UC system. **We've been gifted with great observing facilities, and we've used them extremely effectively. Astrophysics at UCSB is part of the physics department, and our astrophysicists have contributed our share toward reaching a national ranking of 5th**

among physics departments. That actually understates out success, because no account is taken of department size - and we are much smaller than the other top departments.

Edward Wright, UCLA

Much of my career has involved space-based infrared astronomy. Further study of these sources requires ground-based telescopes with cameras and spectrographs. WISE has found hundreds of millions of galaxies and the median redshift of high latitude sources, found using DEIMOS on the Keck telescopes and the UCLA remote observing room, is about 0.4. WISE has found a thousand extremely red sources for which redshifts can usually be found with Keck and LRIS (fluxes around 24th mag), and which run up of z=4.6. These hot dust obscured galaxies, or hotDOGs, are among the most luminous objects in the Universe.

In addition to ongoing WISE follow-up, I have used the Mt Hamilton telescopes to measure the temperature of the CMB, and to survey star fields in the 3.5 micron band in order to determine the CIRB.

My decision to leave MIT and come to UCLA was based in part on the proximity of the Mt. Hamilton facilities to LA, while to observe from MIT required a trip across the country.