Laser-Wielding Robot Probes Exoplanet Systems

The IfA’s Christoph Baranec is leading a team that uses the world’s first robotic laser adaptive optics system—Robo-AO—to explore thousands of exoplanet systems around other stars at resolutions approaching those of the Hubble Space Telescope. The results, published in the *Astrophysical Journal*, shed light on the formation of exotic exoplanet systems and confirm hundreds of exoplanets.

“We’re using Robo-AO’s extreme efficiency to survey in exquisite detail all of the candidate exoplanet host stars that have been discovered by NASA’s Kepler mission,” said Baranec. “While Kepler has an unrivaled ability to discover exoplanets that pass between us and their host star, it comes at the price of reduced image quality, and that’s where Robo-AO excels.”

An international team of astronomers, including IfA’s Harald Ebeling, has used the Hubble Space Telescope to map the mass within a galaxy cluster, originally discovered with Maunakea telescopes, more precisely than ever before.

Clusters of galaxies are the most massive objects in the Universe, comprising hundreds to thousands of galaxies and also enormous amounts of invisible dark matter. They grow through collisions in which smaller clusters merge into ever more massive systems, a process that can temporarily lead to highly complex mass distributions.

Ebeling specializes in finding the rarest, most extreme clusters that are the most rewarding targets for detailed studies of the formation and evolution of cosmic structure. One of the clusters discovered by Ebeling’s Massive Cluster Survey (MACS) group, which used several telescopes on Maunakea, goes by the unpoetic name of MACSJ0416.1-2403.

It was found to be so massive that the cluster was selected for extremely deep observations with the Hubble Space Telescope as part of the Frontier Fields program. The resulting Hubble data show the galaxy distribution within the cluster in stunning detail. The new, ultra-deep observations also reveal a multitude of distorted images of galaxies that are in fact far behind the cluster, bent and often appearing multiple times within the Hubble image of MACSJ0416 due to an effect called gravitational lensing, in which the mass of a foreground object magnifies and distorts more distant objects.

Gravitational lensing by mass concentrations in space comes in two varieties: so-called “strong lensing,” which creates the highly elongated, almost linear images of distant background galaxies visible near the center of the cluster (as predicted by Einstein’s theory of relativity), and “weak lensing,” pioneered by IfA’s Nick Kaiser in the 1990s, which causes much less perceptible, faint, statistical distortions of hundreds of background galaxies viewed at larger distances from the cluster core.

See *Mass Map of Galaxy Cluster*, pg 3
In fact, analysis of the first part of the Robo-AO/Kepler exoplanet host survey is already yielding surprising results. “We're finding that ‘hot Jupiters’—rare giant exoplanets in tight orbits—are almost three times more likely to be found in wide binary star systems than other exoplanets, shedding light on how these exotic objects formed,” said Nicholas Law (University of North Carolina at Chapel Hill), Robo-AO's project scientist. “Going further, Robo-AO's unique capabilities have allowed us to discover even rarer objects: binary star systems where each star has a Kepler-detected planetary system of its own. These systems will be uniquely interesting for studies of how the planets formed—and for science fiction about what life would be like with another planetary system right next door,” continued Law.

Indeed, the first Robo-AO survey, covering 715 Kepler candidate exoplanet hosts, is the single largest scientific adaptive optics survey ever. That record won't stand for very long, as the Robo-AO team is extending the survey to image each and every of the 4,000 Kepler candidate exoplanet hosts, and is ready to observe exoplanet hosts from Kepler's new K2 mission as they are discovered.

The key to Robo-AO's success is its efficiency, allowing it to observe hundreds more targets per night than conventional adaptive optics systems. So far, the Robo-AO system has been used to make over 13,000 observations. “The automation of laser adaptive optics has allowed us to tackle scientific questions that were unimaginable just a few years ago. We can now observe tens of thousands of objects at Hubble-Space-Telescope-like resolution in short periods of time,” Baranec said. “Now that the technology has been proven, we're looking to bring it to the pristine skies of Maunakea, Hawai'i, where it will be even more powerful.”

The other members of the Robo-AO team include researchers from Princeton, Caltech, the University of North Carolina, Harvard, and the Inter-University Centre for Astronomy and Astrophysics in Pune, India, and a student at W. Tresper Clarke High School in Westbury, New York.
Mass Map of Galaxy Cluster

The spectacular images collected of MACSJ0416 during the Frontier Fields program were recently analyzed by members of the team led by Mathilde Jauzac (Durham University, UK. and Astrophysics & Cosmology Research Unit, South Africa). They used both strong- and weak-lensing techniques to infer the cluster mass distribution that creates the many lensing features identified in these data.

Their meticulous search for even the faintest gravitationally lensed images was unprecedentedly successful, resulting in the identification of four times as many lensed background galaxies as were previously known in this system. The result is a mass map of MACSJ0416 that is more precise than any ever derived for any galaxy cluster, showing the highly elongated distribution of dark matter in this merging cluster in great detail and over an enormous range of scales. The study also established MACSJ0416 as a huge cluster indeed, with a measured mass of 160 trillion times the mass of the sun.

“Our analysis of the Frontier Fields data demonstrates impressively how detailed studies of the extremely massive clusters found by MACS can advance our understanding not only of the complexity of cluster formation but in fact of the distant Universe behind these powerful gravitational lenses,” explains Ebeling.

Further investigations of MACSJ0416 are underway, combining the Frontier Fields images with deep X-ray observations of the hot gas within the cluster and with spectroscopic redshifts of the cluster galaxies, measured by Ebeling as part of the follow-up work conducted by the MACS team using Maunakea facilities. Their primary goal is to deduce the merger history of this extreme cluster by establishing its three-dimensional geometry and the trajectories of the clusters involved in the collision.

The galaxy cluster MACSJ0416.1-2403, which was originally discovered with Maunakea telescopes. The researchers used almost 200 images of distant galaxies, whose light has been bent and magnified by this huge cluster, combined with new Hubble data, to measure the total mass of this cluster (as blue tint over photo on right) more precisely than ever before. Credit: ESA/Hubble, NASA, HST Frontier Fields

Tully Wins Three Major Prizes

IfA astronomer Brent Tully is one of four recipients of the 2014 Gruber Foundation Cosmology Prize for his role in understanding the structure and evolution of the nearby universe. He also won the Wempe Award given by the Leibniz Institute for Astrophysics Potsdam (AIP) “in recognition of his groundbreaking research about the structure of galaxies and the large-scale structure of the cosmos,” and is a co-winner of the Viktor Ambartsumian International Prize established in 2009 by the president of Armenia in commemoration of the great Armenian astrophysicist. The Special Astrophysical Observatory in Russia nominated Tully and his Russian collaborator, Igor Karachentsev, for the Ambartsumian prize “for their fundamental contribution in the cosmology of the Local Universe.” They share the prize with Felix Aharonian, who is recognized for his contributions to high-energy astrophysics.

At UH since 1975, Tully came to prominence with the publication of a 1977 paper, written with J. Richard Fisher, proposing a relationship between the masses of galaxies and their luminosities. Measure the mass of a galaxy, and you’ll know the galaxy’s true brightness. Compare the true brightness with its observed brightness, and you’ll know its distance [much as you could calculate the distance of a light bulb if you knew its lumens]. The “Tully-Fisher relation” remains a standard tool in astronomy to this day. It has allowed astronomers to determine distances to galaxies, the key measurement that allows us to view the universe in three dimensions.
Awards, Awards, Awards

IfA faculty, students, and alumni have accumulated a plethora of awards of late. Congratulations to them all.

Brendan Bowler, who completed his dissertation last year at the IfA and is now a postdoctoral fellow at the California Institute of Technology, Joint Center for Planetary Astronomy, has received the Robert J. Trumpler Award given by the Astronomical Society of the Pacific for a recent PhD thesis considered unusually important to astronomy. The title of his thesis is “A Search for Giant Planets Around Low-Mass Stars: Revealing the Architecture of M Dwarf Planetary Systems.”

Faculty members Andrew Howard and Nick Kaiser each won a Regents’ Medal for Excellence in Research, awarded by the University of Hawai‘i Board of Regents “in recognition of scholarly contributions that expand the boundaries of knowledge and enrich the lives of students and the community.” Howard was hailed for discovering dozens of exoplanets with telescopes both in Hawai‘i and in space, and for exploring their chemical compositions and formation histories. His research team was the first to demonstrate that an Earth-size exoplanet is made of the same materials as Earth, namely, rock and iron, and that temperate planets the size of Earth are common in our Milky Way Galaxy.

Kaiser was recognized for his groundbreaking work in cosmology. His contributions have included work on the theoretical interpretation of fluctuations in the cosmic microwave background, on the phenomenon of “biased galaxy clustering,” and on cosmic flows, galaxy clustering, and gravitational lensing. He was also the principal investigator for the Pan-STARRS project.

At the same awards ceremony, graduate student Jabran Zahid received a UH Mānoa Award for Student Excellence in Research at the Doctoral Level for his work on the formation and evolution of galaxies. He has measured the chemical evolution of the Universe by using observations of the heavy elements in galaxies across cosmic time. He has also contributed to the understanding of galaxy formation and evolution by theoretically modeling the chemical evolution of the Universe. He is continuing his career as the Clay Prize Postdoctoral Fellow at the Harvard-Smithsonian Center for Astrophysics.

Ryan Swindle won the IfA Achievement Rewards for College Scientists (ARCS) Scholar Award for 2014. This $5,000 prize was announced at the annual ARCS Banquet May 5.

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A Major Contract for Inouye Solar Telescope Instrument

The National Science Foundation and the Daniel K. Inouye Solar Telescope (DKIST) have announced the award of a major contract to the IfA to build the Cryogenic Near Infrared Spectropolarimeter (Cryo-NIRSP) for the new solar telescope, which is now under construction on Haleakalā.

This complex $5 million instrument will allow astronomers to measure solar magnetism beyond the Sun in order to understand how that energy interacts with Earth’s space environment. It will be built at the UH Advanced Technology Research Center on Maui and will be completed in time for first-light observations with DKIST in 2019.

The CryoNIRSP team on Maui is led by Principal Investigator Jeff Kuhn, Project Manager Tim Bond, and Instrument Scientist Andre Fehlmann.

“The CryoNIRSP instrument will be one of the largest astronomical instruments the IfA has built. It will provide the international community with a detector that brings nighttime sensitivity for observing the relatively faint outer atmosphere of the Sun to the world’s largest daytime telescope,” said Kuhn.

“It is the Sun’s magnetism that causes most of the Sun’s influence on Earth. We know it controls the explosive energy release from the Sun that damages our technology and the Sun’s brightness variability that affects our climate,” added Kuhn.

The DKIST was formerly known as the Advanced Technology Solar Telescope (ATST). It was renamed in honor of the late Senator Daniel K. Inouye in December 2013.
TMT Receives Final Approval

It’s finally “go” for construction of the Thirty Meter Telescope (TMT) on Maunakea. On July 25 the Hawai‘i Board of Land and Natural Resources approved the required sublease, the last step in the permitting process. The next-generation TMT will ensure that Maunakea Observatories will remain the foremost observing site in the northern hemisphere for decades.

Previously, Kahu Ku‘u Mauna (a volunteer community-based council whose members are from the native Hawaiian community) and the Maunakea Management Board reviewed, and the University of Hawai‘i Board of Regents approved, the proposed TMT sublease. This final approval from the Board of Land and Natural Resources allows TMT to begin on-site construction. TMT announced it would begin the initial phase of construction, with activities near the summit scheduled to start later this year.

The start of TMT on-site construction will directly benefit the local Hawaiian community. TMT will now make its first annual contribution to The Hawaii Island New Knowledge (THINK) Fund, a program that promotes science, technology, engineering, and math (STEM) education across grades K–12 and postsecondary education. Over the life of the TMT sublease, TMT will contribute $1 million per year to the THINK Fund.

In the construction sector, TMT will create about 300 full-time construction jobs. TMT has committed to hire union workers for these positions. When TMT becomes operational in about 2022, it will have a staff of 120–140 that will be drawn as much as possible from Hawai‘i Island’s available labor pool. In the meantime, a workforce pipeline program will educate and train island residents for jobs with TMT, as well as other observatories and high-tech industries.

HawaiiCon www.hawaiiicon.com

HawaiiCon, which will take place at Hawai‘i Island’s Hapuna Beach Prince Hotel September 12–14, bills itself as “the world’s first sci-fi, science, and fantasy tropical vacation convention.” As a sponsor, IfA will play a major role in providing the science component.

Modeled on Comic Con, it will feature cast members from Stargate Atlantis, Battlestar Galactica, and other science fiction series, comic book artists and writers, and those engaged in “cosplay” (costume play), as well as chances to enjoy Hawai‘i.

IfA will provide a remote-observing experience using the Las Cumbres Observatory Global Telescope Network and speakers on scientific subjects, including killer asteroids, exoplanets, and black holes. There will also be a multidisciplinary panel of UH faculty discussing “Apocalypse How: Scientific Views of Threats to Humanity” led by Karen Meech, the principal investigator for the UH NASA Astrobiology Institute, who will speak about the cycles of extinction. Other panelists will talk about the dangers of volcanoes, the dangers of a takeover by computers, and biological hazards.

Roy Gal, IfA astronomer and outreach coordinator, said, “The HawaiiCon organizers feel (and I agree) that a sci-fi fan is also a person with a great interest in real science, especially astronomy. Given Hawai‘i’s unique role in astronomy, it’s a great opportunity to enhance public knowledge of the field and Hawai‘i’s role in it.”
Students who have participated in HI STAR (Hawai‘i Student/Teacher Astronomy Research), an IfA program that encourages middle and high school students to excel in the sciences by teaching them how to do astronomical research, picked up a bundle of awards at the 2014 Intel International Science and Engineering Fair (ISEF) in Los Angeles. Six of the 25 students from Hawai‘i who went to ISEF were students who had previously attended HI STAR, and nine of the 18 awards won by Hawai‘i students were won by HI STAR alumni.

Sarah Jenkins: “Hot Biology: Use of Thermal Imaging to Detect Nesting Behaviors of the Endangered Hawaiian Coot”—Third Place in Animal Science, and a full tuition scholarship from Drexel University.

Christopher Kim and Matthew Thomas Sturm: “Observational Detection of Solar g-mode Oscillations Using Doppler Velocity Signals”—Third Place in Physics and Astronomy, and the First Physical Science Award from Sigma Xi, The Scientific Research Society

Stephanie Spear: “Rocks of the Rainbow: Asteroid Classification Using SDSS Filters”—Fourth Place in Physics and Astronomy, Certificate of Honorable Mention from the American Association of Physics Teachers and the American Physical Society, the Third Award from the American Geosciences Institute, the New American University Provost Scholarship from Arizona State University, and the Second Award given by NASA.

Kayla Ishida: “Predicting the Strength of Solar Flares Using Sunspot Characteristics”—Alternate status for a summer internship at the National Oceanic and Atmospheric Administration (NOAA).

Several students who have been HI STAR participants also gave impressive TEDx youth talks that can be found on YouTube. Stephanie Spear gave a talk entitled “Bigger Isn’t Necessarily Better” at a TEDx youth event held at Kamehameha School on O‘ahu. McKayla Wandell spoke about “Not Being Defined as ‘X,’” Matthew Thomas Sturm’s talk was “Magnetic Suspension, Levitation and Suspension,” and Aaron Rohozinski spoke about “The Nature of Originality” at a TEDx youth event entitled “Imagining a Better Tomorrow” held at Seabury Hall, a private school on Maui.

TED—Technology, Entertainment and Design—is a nonprofit organization devoted to spreading ideas, usually in the form of short, powerful talks. TEDx events, which are independently run, share ideas in communities around the world.
A Busy Summer of Outreach
by Roy Gal, Astronomer and IfA Outreach Specialist

The summer of 2014 has been packed with public programs across the state. We kicked off this unusually busy season with our free Sheraton Waikiki Explorers of the Universe lecture at the Kennedy Theatre on May 10. Prof. Alex Filippenko of the University of California, Berkeley spoke on “The Big Bang Theory, Inflation, and the Multiverse: An English Major’s Introduction to the Birth and Early Evolution of the Universe.” Dr. Filippenko, the only member of both teams whose leaders were awarded the 2011 Nobel Prize in Physics, and nine-time “Best Professor” at Berkeley, gave a very entertaining talk about the current view of our Universe and the possibility that it is but one of a huge number of universes. The sold out lecture ended with a great question-and-answer session, with a handful of children asking amazing questions.

We also continued our partnership with the UH Mānoa Outreach College through their Statewide Cultural Exchange Program (SCEP), which brings UH Mānoa experts into public libraries to share their knowledge. IfA faculty, staff, and students visited six libraries throughout the state. On Kaua‘i, astronomer Andrew Howard gave a talk in Princeville on extrasolar planets, and two of our graduate students traveled to Waimea with our sun-viewing equipment for daytime solar viewing. On Maui, J. D. Armstrong braved the twisty Hāna Highway to demonstrate how we learn about the Universe with a light and spectra activity. On O‘ahu, we were all over the island, with our scale model solar system in Kaimuki and Waimānalo, and a light and spectra demonstration in Kahuku. These programs have been very popular, and we’re extremely happy that libraries have provided glowing reviews of our events from this past spring and are inviting us back to do new activities in subsequent semesters.

We also partnered with the Pacific Aviation Museum (PAM) to conduct our second Boy Scouts astronomy merit badge workshop. IfA graduate students Mike Lum and Matt Hosek used a suite of fun, hands-on activities developed by a team of IfA astronomers, PAM staff, and Boy Scout troop leaders to satisfy the requirements of the astronomy merit badge. Instead of a day of classroom lectures, these kids made use of our portable planetarium and telescopes to explore the Sun and the solar system.

We are always on the lookout for venues to reach new audiences. On August 2 and 3, we were at the Navy Exchange (NEX) Back-to-School event from 10 a.m. to 2 p.m. doing solar viewing. This is a great opportunity to serve the men and women who serve our country and often spend only a short time in Hawai‘i. Two weeks later, on August 16 and 17, we participated in the Pacific Aviation Museum’s Biggest Little Airshow. This fantastic event attracted about 10,000 attendees to enjoy flying scale model airplanes and doing family-friendly activities, including our solar viewing station.
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From the Director

We’ve recently received two pieces of exciting and long-anticipated news. On July 25 the Hawai‘i Board of Land and Natural Resources approved the required sublease, the last approval necessary before construction of the Thirty Meter Telescope on Maunakea can begin [see story in this issue]. On August 21, the UH Board of Regents approved two new undergraduate astronomy degrees at UH Mānoa, a BA degree in astronomy and a BS degree in astrophysics.

The BA degree is intended for students planning careers as planetarium or observatory staff, teachers, science writers, or other science and technology staff. The BS degree will lead to a career in scientific research by preparing students for graduate work in astronomy, astrophysics, or physics.

Although UH Mānoa has long had a distinguished graduate program in astronomy and has offered a limited number of undergraduate astronomy courses, it has not had an undergraduate degree program. The new programs will give undergraduate students in Hawai‘i, especially those on O‘ahu, the opportunity to consider a career in astronomy, and to participate in the discoveries being made and the research being carried out at the world-class astronomical facilities in their own state.

IfA is already cooperating with UH Hilo to support the existing BS degree in astronomy there. In particular, we plan to jointly raise funds to place a robotic educational telescope at the existing Hōkū Ke‘a site on Maunakea that will be shared by the UH Hilo and UH Mānoa undergraduate programs.

I am so pleased that these programs received enthusiastic support from all the bodies involved in the approval process required to establish them. The Mānoa Faculty Senate voted unanimously to recommend them, something that had not happened in this body for many years. The UH Council of Chief Academic Officers passed the proposal with flying colors, and finally, members of the Subcommittee for Academic Affairs of the Board of Regents demonstrated great excitement and support for both programs.

With the completion of the Daniel K. Inouye Solar Telescope on Haleakalā and the Thirty Meter Telescope on Maunakea, the size of the astronomy workforce in Hawai‘i is expected to grow by about 20 percent over the next decade. These degrees are one of the factors that will enable Hawai‘i residents to fill some of these positions.

In anticipation of the approval for these degrees, the UH Mānoa Department of Physics & Astronomy began offering the lower-level courses required for these majors in 2012, so there are already some potential majors in the pipeline. I look forward to graduates of the astrophysics program attending graduate school at the IFA.