INSTITUTE FOR ASTROPHYSICS UNIVERSITY OF HAWAI’I

Nā Kilo Hōkū
THE ONES WHO LOOK TO THE STARS

Imaging Other Worlds: NICI Planet-Finding Campaign
by Michael C. Liu

One of the most exciting developments in astronomy has been the discovery and characterization of exoplanets—planets orbiting stars other than our Sun. Our understanding of these objects has advanced by leaps and bounds over the past 15 years, since the discovery of the first exoplanet around the Sun-like star 51 Pegasi in 1995.

We now are entering a rich and special time for such studies. The current exoplanet census now exceeds 400 objects, most of them with masses comparable to the gas-giant planet Jupiter, which has a mass of one-thousandth that of the Sun, or 300 times that of Earth. Most exoplanets have been identified by the very subtle gravitational tug they exert on their host stars. While these discoveries have been groundbreaking, such planets are studied only indirectly. Other planets have been found as they transit across the face of their host stars, thereby diminishing the amount of light we detect from them. Such planets can be studied in great detail, but they orbit very close to their stars, making them unlike any planets in our solar system.

The next major advance is direct imaging, that is, taking actual digital images of planets around other stars. Directly detecting light from exoplanets opens the door to a host of new information about their properties (temperature, composition, etc.) and their formation. Direct detection is Please see NICI, pg 2

Planet Detected in Habitable Zone of Nearby Star
by Louise Good

A team led by IfA astronomer Nader Haghighipour has discovered a planet with about the same mass as Saturn in the habitable zone of a star 36 light-years from Earth. Its detection is important because it indicates that observational techniques are on the right track for finding habitable low-mass rocky planets similar to Earth,” according to Haghighipour.

A planet is considered to be in the habitable zone if its temperature is just right for having liquid water. The approximate surface temperature of the above-mentioned newly discovered planet is about minus 42 degrees F, which was calculated by considering the surface temperature of the star, the planet’s size, the proportion of the star’s light that the planet may reflect, and the time that it spends in close proximity to the star. This temperature is colder than the value one gets for Earth for the same kind of calculation. However, if the planet’s atmosphere holds in heat sufficiently, then the surface temperature will certainly be warmer than minus 42 degrees.

The planet (HIP 57050b) circles its central star (HIP 57050) every 41 days. The star, which is classified as an M dwarf, has a radius approximately 0.4 times that of the Sun, and has a mass about one-third of the Sun’s. “Because HIP 57050b is a giant planet, it is unlikely that it is habitable,” Haghighipour notes.

In the quest for potentially habitable planets, the nearest stars are of special importance. We know their precise distances, as well as their masses, sizes, and temperatures, and they are the only stars for which follow-up by Please see Planet Detected, pg 2
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incredibly challenging. We see the planets in our own solar system because they reflect light from the Sun. Imaging the reflected light of exoplanets is currently impossible because the light reflected by the planets is swamped by the glare of their host stars, which are about a billion times brighter. However, when gas-giant planets are young, they also emit their own light at infrared wavelengths, by releasing the heat stored in their interiors at the time of formation. This makes young planets much easier to detect, since they are only(!) about one million times fainter than their parent star. In 2008, astronomers took the first direct images of young gas-giant exoplanets, thereby opening the door to this new way of learning about them.

My research group is leading an international effort known as the Gemini NICI Planet-Finding Campaign to expand the census of exoplanets detected by direct imaging. NICI (the Near-Infrared Coronagraphic Imager) is a powerful new instrument installed on the Gemini South 8.1-meter telescope in Chile, the twin of the Gemini North telescope on Mauna Kea. Most astronomical instruments can do multiple kinds of observations, but NICI was designed to do only one thing very well, namely, image exoplanets directly. NICI was built by Doug Toomey of Mauna Kea Infrared in Hilo, with heavy involvement by IfA faculty members Christ Ftaclas and Mark Chun, and funding from NASA. NICI is designed as a complete end-to-end system for exoplanet imaging. It is based on an advanced adaptive optics system that corrects for the blurring of astronomical images caused by Earth’s turbulent atmosphere.

Since December 2008, we have been using NICI to obtain very sensitive images of 300 nearby young stars (within about 200 light-years) to search for gas-giant planets in emitted light. The campaign will take about three years and obtain a total of 50 nights of observations. This makes it the largest single program ever carried out at the Gemini telescopes. By having a major campaign, it is possible to assemble a large-scale coherent science program with a unified set of goals, observing methods, and data analysis techniques. While the observations are carried out in Chile, the planning and analysis are done here at the IfA, with postdoctoral fellow Zahed Wahhaj and Hubble Fellow Beth Biller being key contributors.

The campaign is about halfway finished. We have imaged about 180 stars so far, already making NICI the largest direct imaging search to date. However, in some sense, we are just getting started. Many of the stars we have imaged have very faint companions next to them, but we do not yet know what these are. They could be gas-giant planets in orbit around these stars, or they could be ordinary background stars that are much farther away but by chance are projected on the sky nearby. The way to check is to make a second set of observations about one year later to see if the faint candidates move with the target star, thereby proving that they are gravitationally bound together. We are in the process of doing that right now. Once candidates are confirmed, we can learn a great deal about the properties of young planets through dedicated follow-up observations to measure their brightnesses, colors, atmospheres, and orbits.

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astrometry and direct imaging is possible. While the majority of the currently known extrasolar planets have been detected around larger nearby stars, more than 70 percent of the nearest stars are M dwarfs. As such, these stars have the special properties (distances and masses) that drive exoplanetary science, astrobiology, and the next generation of interferometry and direct imaging missions.

The low surface temperatures of M dwarfs place their habitable zones at distances that are approximately 10 to 20 percent of Earth’s distance from the Sun. These distances correspond to orbital periods of 20–50 days, another advantage of M dwarfs as potential targets for detecting habitable planets—because of their small masses, these stars respond more noticeably to the gravitational forces of close-in planets.

Haghighipour adds that it is interesting to speculate about the possible presence of a moon around HIP 57050b. While it is not out of the question that HIP 57050b could harbor a moon, and that moon would thus be in the habitable zone of the parent star, an object with only one-fifth the mass of Mars is probably not a particularly good prospect for habitability from various standpoints. Furthermore, direct detection of such a moon would be extremely challenging.
Two IfA astronomers are the recipients of senior research awards from the Alexander von Humboldt Foundation in Germany. These research awards are intended to recognize the lifelong academic achievements of the awardees, are granted on the basis of nominations by eminent German scholars, and enable awardees to come to Germany to work on a research project with a German host.

IfA Director Rolf-Peter Kudritzki, who will relinquish the IfA directorship at the end of 2010, plans to use his Humboldt award during a 2011 sabbatical in Germany to investigate the physics of galaxies.

Kudritzki will use the brightest stars in the Universe as tools to dissect galaxies. He will analyze spectra of hundreds of supergiant stars (stars with radii as large as 300 times the Sun and a hundred thousand times brighter) in distant galaxies. By applying completely new methods developed with his collaborators, who include IfA astronomers Fabio Bresolin and Miguel Urbankeja, Kudritzki will be able to use the spectra to determine the chemical compositions of galaxies and their distances from us. For instance, in spiral galaxies like our own Milky Way, the stars in the center have a higher percentage of elements heavier than hydrogen and helium than the stars at the edges of the rotating spiral arms.

Data about the chemical composition of galaxies can be used to test the present theory about how galaxies have formed in an expanding Universe that is dominated by cold dark matter (matter that does not interact with any form of light and whose constituent particles move more slowly than light) and dark energy (the mysterious force that is accelerating the expansion of the Universe). In fact, chemical analysis is one of the very few ways to test this scenario quantitatively. So far, the present knowledge of the chemical composition of spiral galaxies is very uncertain. Kudritzki’s new method will be the first to provide accurate numbers.

“This project is entirely new. Nobody has ever done anything like this, except Fabio, Miguel, and me. Thus, I am truly excited and look forward to spending all my energy and time on it. I will use all the largest telescopes in the world for this project, including those on Mauna Kea and in Chile, and also the Hubble Space Telescope,” Kudritzki said.

Jeff Kuhn received his award on the strength of his cumulative research studying the Sun. This is the first time that a solar scientist from the United States has been granted the prize. Kuhn’s research has often focused on finding new ways to understand the solar interior by using observations of its surface made by instruments on the ground and in space. His group recently found that, unlike almost everything else that we measure about the Sun, it is constant in diameter to better than a few parts in a million (see article on page 6). Kuhn said, “I plan to use this award to develop new models of how and why the solar cycle is so dependent on the death cycle of sunspots.” He added that the physics is not known but critical to understanding how all stars evolve and change, and that “this understanding may ultimately help us predict how and when a changing Sun affects Earth’s climate.”

IfA astronomer J. Patrick Henry spent the spring in Germany on a Humboldt award that is a follow-up to the one he received in 2003. Henry is one of the world’s experts on the cosmological evolution of clusters of galaxies. He pioneered the use of X-ray observations of clusters to understand how the entire Universe grows. His work provided some of the earliest evidence for what has become the standard description of that growth, including the idea that most matter in the Universe is dark matter. While in Germany, Henry finished a paper describing the properties of one of the most distant clusters of galaxies yet found. These very distant objects let astronomers actually see how clusters of galaxies are formed rather than deducing how they formed from studying the properties of fully grown examples.

IfA astronomer David Sanders is also a previous winner of a Humboldt research award.
Open House, Astroday Events

Hundreds of visitors attended the Ma‘noa Open House, on April 18. Some came to see a fresnel lens melt a penny and fry an egg. Others came to hear the talks, such as Robert Jedicke explaining the connection between the origin of the Universe and the Large Hadron Collider. Children enjoyed making comets and sundials, seeing a show in the StarLab planetarium, packaging an egg so that it would survive a drop from the second floor (the Mars Drop), and launching a bottle rocket. While the weather cooperated, visitors viewed sunspots and Venus.
The ninth annual AstroDay Festival, which celebrates astronomy and Hawaiian culture, took place on May 1 at Prince Kūhiō Plaza in Hilo. More than 30 scientific and cultural booths provided attendees with the opportunity to play games, see planetarium shows and demonstrations, and win Celestron telescopes. As always, there was good entertainment, too. At the beginning of the festivities, members of the Mauna Kea Observatories Outreach Committee honored AstroDay organizer (and IfA Science Education and Public Outreach Officer) Gary Fujihara for his efforts to bring astronomy to the people.

Ma‘noa Open House photos by Karen Teramura.
Galaxy Collisions Create Large Black Holes and Quasars

Giant black holes at the centers of galaxies grow mainly as a result of intergalactic collisions, according to IfA astronomer Ezequiel Treister, leader of a study published in March. As gas clouds in galaxies are sucked into the central black hole, they emit vast amounts of radiation, giving rise to quasars, which are very luminous active galactic nuclei. “We find that these growing black holes are originally hidden by large amounts of dust, but after 10–100 million years this dust is blown out by the strong radiation pressure, leaving a naked quasar that is visible at optical wavelengths and keeps shining for another 100 million years,” Treister said.

For this study, Treister and his colleagues combined data obtained with the Hubble, Chandra, and Spitzer space observatories to identify a large number of obscured, dust-enshrouded quasars at very large distances, up 11 billion light-years away, seen as they were when the Universe was still in its infancy. “For many years, astronomers believed that these sources were very rare. Now we are seeing them everywhere!” Treister said. Because most of the emission from these obscured quasars is hidden, astronomers looked at infrared wavelengths for signs of very hot dust, and in X-rays, which are less affected by obscuration. The investigators discovered that the number of obscured quasars relative to the unobscured ones was significantly larger in the early Universe than it is now.

Other team members are Priyamvada Natarajan, Meg Urry, and Kevin Schawinski (Yale), IfA astronomer David Sanders, and former IfA graduate student Jeyhan Kartaltepe, who is now with the National Optical Astronomy Observatories in Arizona.
When, How Did Earth Become Life Friendly?

On March 31, a Frontiers of Astronomy Community Lecture presented by the IfA and the UH NASA Astrobiology Institute (NAI) attempted to answer the question, “When and how did our planet become conducive to life?”

A panel consisting of Jeff Taylor, a geologist from the Hawai‘i Institute of Geophysics and Planetology and a member of the UH NAI team; Karen Meech, IfA astronomer and principal investigator for UH NAI; and Steve Mojzsis from the Department of Geological Sciences at the University of Colorado explained what we know so far about this process. Steve Freeland, an evolutionary biologist who is now the project manager of UH NAI, served as moderator.

Freeland explained that NASA organized the NASA Astrobiology Institute (NAI) in 1998 to study the origins, evolution, distribution, and future of life in the Universe and that UH NAI is one of 14 NAI centers located throughout the United States. Life on Earth, he said, is amazingly diverse, with only a small fraction of it visible to the unaided eye.

So how did Earth, at first a ball of molten rock, evolve into a planet with a surface of blue oceans and green lands filled with life? First, it was necessary to build a planet. Taylor spoke about what he termed the “haphazard” construction of our planet. In the solar nebula, dust grains collided and stuck together. Collisions led to larger and larger bodies. Less volatile elements and compounds, such as ferrous oxide (FeO), condensed out of the solar nebula at the higher temperatures prevalent in the inner solar system, so early Earth was mostly metallic and rocky.

But what about water, which condenses at a much lower temperature? Liquid water is required for life as we know it, so next Meech discussed the origin of Earth’s water. There is evidence of some water in many locations in the solar system—on Saturn’s moon Enceladus, on Mars, and on the Moon—but generally speaking, the inner planets are dry. Even on Earth, the oceans account for only 0.023 percent of the planet’s mass, and the total amount of water is estimated at no more than a tenth of a percent of Earth’s mass. The exact amount of water on our planet is undetermined, because scientists can only estimate how much water is deep beneath Earth’s surface.

So where did Earth’s water come from? Was it captured from the solar nebula because water molecules stuck to the dust that eventually formed the planet? Did a major impact cause Earth’s surface to melt into a magma ocean, after which hydrogen in the atmosphere reacted with oxygen to form water? Or did it arrive when asteroids or comets collided with Earth? Scientists are trying to match the ratio of deuterium (D) to hydrogen (H) in the water from these sources with that on Earth, but such attempts may not be accurate because we do not know the D/H ratio for water inside Earth. Meech concluded by saying Earth’s water probably came from many sources.

Mojzsis spoke about how Earth became habitable, and how it is a laboratory in the search for life elsewhere. Evidence shows that about 4.53 billion years ago (about 40 million years after the solar system formed), a large body collided with the proto-Earth, causing the formation of the Moon and vaporizing magma on both bodies. After the collision, Earth cooled rapidly. Two million years later, it had an atmosphere of rock vapor and water vapor. Forty million to 600 million years after the solar system formed, Earth had water and a crust, and was ready for life. We know this because geologists have found rocks that are 4.3 billion years old and include minerals that required abundant water to form.

It appears, then, that the answer to the question, “When and how did our planet become conducive to life?” is “very early, and we still have much to learn.”

www.ifahawaii.edu/UHNAI/
Dear Friends of the Institute for Astronomy,

Summer on a university campus is often a relatively quiet time, but so far, this summer has not been quiet at IfA Mānoa. While some of our faculty and staff are on out-of-town trips, they have more than been replaced by visitors from afar. First, undergraduates from throughout the United States (and one from France) arrived for the tenth annual Research Experiences for Undergraduate program. Each student will work with a faculty mentor on a research project throughout the summer. Eight of them are at IfA Mānoa, four are at IfA Hilo, and two are on Maui.

On June 4, a group of Hawai`i students entering grades 7–11 and their teachers came to Mānoa to participate in the Hawai`i Student/Teacher Astronomy (HI STAR) program. Sponsored by the UH NASA Astrobiology Institute, with additional support from private donors, HI STAR is a weeklong “astronomy boot camp” for students and teachers who are passionate about astronomy and want to learn more about it. At this very hands-on workshop, they learned how to make observations, do image processing, and use software to measure the position and brightness of the observed objects.

From June 7 to 10, 65 people attended the 2010 COSMOS Team Meeting here. COSMOS—the Cosmic Evolution Survey—has used the Hubble Space Telescope and other space- and ground-based observatories to survey a two-square-degree region of the sky in unprecedented detail. Team members came from 10 countries to share information and plan future research.

Our solar scientists on Maui have also been busy. They hosted the Sixth Solar Polarization Workshop May 30 through June 4 at the Sheraton Maui Resort and Spa. One hundred scientists from throughout the world gathered to talk about using the technique called “polarimetry” to study the Sun and other stars.

Have a safe and enjoyable summer.

Aloha!
Rolf-Peter Kudritzki
Director, Institute for Astronomy