Discovering the Early Monsters of the Universe

by Lennox Cowie

Over the last decade, studies of galaxy formation have moved to cover all stages of galaxy formation, from the cosmic dawn when galaxies first began to shine, to the present day, when galaxies seem to be approaching the end of their lives. Along with my collaborators, Amy Barger, Wei-Hao Wang, and Jonathan Williams, I have been working toward taking a cosmic census of the galaxies in the young Universe and determining how they evolved into what we see today.

At the end of the 1990s, Amy, David Sanders, and I discovered that when the Universe was about a quarter of its present age, galaxies with individual light outputs equivalent to many thousands of our own Milky Way dominated the Universe. By now these monster galaxies have almost died out, leaving much more numerous smaller galaxies. Intriguingly, by using a new telescope on Mauna Kea, we have recently discovered that these monsters were fired up even earlier than we had previously thought—and may, in fact, have dominated all of the star formation that occurred very early in the Universe’s history.

With their enormous bursts of star formation, one might have thought that these extremely luminous galaxies would be fairly easy to see, even from far across the Universe. However, given their late discovery, this was clearly not the case. How were they escaping detection? The reason we had such a hard time finding them also means that they are very fainter. The odd shape is caused by its fast rotation—the rapid spinning causes it to stretch out into the football-like shape we observe.

Haumea: The Strangest Icy Rock at the Edge of the Solar System

by Emily Schaller, Hubble Fellow

Orbiting the Sun at a distance 43 times that of Earth in a region of space called the Kuiper Belt is a dwarf planet named after the Hawaiian goddess of childbirth and fertility, Haumea. There are now so many dwarf planets known in the Kuiper Belt (Pluto was the first) that it is hard to keep track of them all. Haumea distinguishes itself by being one of the most interesting and strangest objects in the entire solar system.

Soon after its discovery in 2005, astronomers noticed the brightness of Haumea increased and decreased every two hours. This variation is due to Haumea’s strange shape and fast rotation. Haumea is shaped like a football and rotates end over end every four hours. When the long end is facing us, Haumea is brighter, but when all we see is its short end, it is much fainter. The odd shape is caused by its fast rotation—the rapid spinning causes it to stretch out into the football-like shape we observe.

Haumea has two small moons orbiting it, Hi’iaka and Namaka, that are named for the children of the goddess. Their existence has enabled astronomers to “weigh” Haumea by watching how long the moons take to complete their orbits. If an object is very massive, its moons will whip around it very fast, but if it is light, they will orbit more slowly. It turns out that Haumea is very massive for its size. This means that unlike most large Kuiper Belt objects, which are made up of about half water ice and half rock, Haumea is almost purely rock. Interestingly, though, spectral observations of the Icy Rock.
Icy Rock

light coming off of Haumea’s surface have revealed that it is covered not with rock, but with pure water ice. Haumea is a large rock with a thin coating of water ice on its surface, like an M&M but without the chocolate.

In the outer solar system, most large objects are thought to have a rocky core surrounded by a water-ice mantle. Our observations of Haumea suggest that it probably experienced a large collision with an object of a similar size early in its history. This collision stripped off most of its ice, left it spinning rapidly, and formed its two moons. Recently, small chunks of nearly pure water ice have been discovered in orbits similar to that of Haumea. These chunks are likely additional pieces of its icy mantle.

In a stroke of astronomical good luck, Namaka, the smaller of the two moons, is circling Haumea in an orbit almost exactly edge-on as seen from Earth. Every nine days Namaka passes either directly in front of or directly behind Haumea, causing the entire system to become fainter by a very small amount. These “mutual events” last for about an hour and will provide a wealth of information about the Haumea system that would otherwise be totally unavailable to us.

For example, the size and shape of Haumea is uncertain by several hundred miles. Haumea is so far away that it looks not much different from a point of light even through the largest telescopes. However, measuring the exact timing of the dip in brightness will allow us to determine Haumea’s size very precisely (down to several tens of miles). The various paths that Namaka takes across Haumea over the course of several years will also allow us to precisely determine Haumea’s odd shape.

I observed the first of these mutual events using the UH 2.2-meter (88-inch) telescope on January 31 and will observe several more over the coming months. Unfortunately, these events will not last forever—the alignment of Haumea and Namaka as seen from Earth will last for several years, but then will not occur again for another 140 years.

Early Monsters

is that their violent activity is hidden from view at visual wavelengths. These galaxies were surrounded by huge amounts of dust and gas. Dust absorbs starlight produced within galaxies and reradiates it as a warm glow at longer wavelengths. In fact, the obscuration of these galaxies was so great that it required observations from a new camera—the Submillimeter Common-User Bolometer Array (SCUBA)—on the 15-meter (49-foot) James Clerk Maxwell Telescope (JCMT) on Mauna Kea to reveal that such powerful galaxies even existed! (Submillimeter astronomy studies the sky at wavelengths from about 0.01 to 0.04 inches, which is the short end of the radio part of the electromagnetic spectrum.)

SCUBA revolutionized our thinking about galaxy formation and evolution. But SCUBA’s low resolution meant that the one thing it could not do was provide us with accurate positions for the galaxies. This made it very difficult to study these galaxies at other wavelengths, which we need to do to ascertain the properties of the galaxies in more detail and to determine their distances. For some of the SCUBA sources, we were able to use higher-resolution observations made at longer radio wavelengths to get around this problem. Spectroscopic follow-up of these sources with the Keck telescopes revealed that they had existed 2–3 billion years after the Big Bang. However, studying the rest of the galaxies found with SCUBA required a new telescope on Mauna Kea, the Submillimeter Array (SMA), which consists of eight 6-meter (20-foot) radio dishes that are used together.

Recent observations with the SMA have given us another exciting result: dusty, extremely luminous galaxies teeming with newly formed stars existed less than 1.5 billion years after the Big Bang. These sources are so faint at visual wavelengths that we could never have discovered them without the submillimeter observations. Our discovery of these massive young sources may present yet another serious challenge to our current understanding of galaxy formation and evolution.

We expect even more discoveries at submillimeter wavelengths with future telescopes and instrumentation. The next generation submillimeter camera, SCUBA-2, is scheduled to begin operations on the JCMT on Mauna Kea soon. It will cover large areas of sky up to a thousand times faster than SCUBA, enabling us to detect substantial numbers of galaxies. Follow-up observations with future telescopes, such as the Atacama Large Millimeter Array (ALMA), an international facility with a major U.S. investment that is now being constructed in Chile, will enable us to learn more about this important population. Soon we may know just when the very first monster galaxies appeared.
The annual Open House at IfA Mānoa, which usually takes place on the last Sunday in April, has been moved to April 5 to coincide with a global International Year of Astronomy (IYA) project called “100 Hours of Astronomy,” which officially begins on April 2 at 2 a.m. HST and ends at 6 a.m. on April 6.

Observing opportunities at the Open House will include sunspot viewing and remote observing with the NASA Infrared Telescope on Mauna Kea. For the children, there will be shows in the StarLab portable planetarium, bottle rocket launching, the Mars drop (packaging a raw egg so that it lands safely), sundial making, and a Lego Moon base. For people of all ages there will be a variety of demonstrations and interactive activities, Ask an Astronomer, laboratory tours, and talks about the latest developments in astronomy.

During the 100 hours event, astronomers at professional research observatories around the world will take viewers inside their telescope domes and control rooms during a live 24-hour webcast. The webcast will begin at 11 p.m. HST on April 2 with the observatories atop Mauna Kea in Hawai’i and move westward to Australia and New Zealand, Asia, Europe, and North and South America. It will end on the U.S. West Coast.

Cowie Wins Heineman Prize

IfA astronomer Lennox Cowie has been awarded the 2009 Dannie Heineman Prize for Astrophysics by the American Astronomical Society and American Institute of Physics for his outstanding work in the field of astrophysics. The prize will be awarded at the American Astronomical Society meeting in Washington, D.C., in January 2010.

Established in 1979, the Heineman Prize honors Dannie Heineman, a Belgian-American engineer and businessman who was a prolific sponsor of science, especially through the Heineman Foundation.

Cowie is considered a world-leading expert in the field of cosmology and galaxy evolution and formation. He received the prestigious prize for his exceptional work at the IfA, specifically for his research with telescopes on Mauna Kea on the Big Island. The prize citation reads, “for his innovative observations and studies of the distant universe, which have significantly advanced our understanding of the formation and evolution of galaxies.”

Cowie received his PhD in theoretical physics from Harvard University in 1976. Prior to joining IfA in 1986, he held appointments at Princeton, MIT, and the Space Telescope Science Institute. He served as IfA associate director from 1986 to 1997, and was awarded the UH Regents’ Medal for Excellence in Research in 1998.

With over 25 years experience as an astronomer, Cowie has been the recipient of several esteemed awards—including the Bok Prize from Harvard University in 1984 and the American Astronomical Society Warner Prize in 1985—and was designated as a highly cited author of the Science Citation Index in 2003.

Cowie was elected a fellow of the Royal Society of the United Kingdom in 2004. The Royal Society, sometimes described as Britain’s national academy, is the oldest continuously functioning scientific society in the world.
Tomo Goto is a fellow of the Japan Society for the Promotion of Science (JSPS). He has come to IfA to work with David Sanders on luminous infrared galaxies. Soon after arriving at IfA last April, he organized a weekly extragalactic discussion group at which an IfA astronomer or a visitor presents findings from his or her research. He received his PhD from the University of Tokyo in 2003 and has also worked at Carnegie Mellon and Johns Hopkins universities, and at the Institute of Space and Astronautical Science, a part of JAXA, the Japanese equivalent of NASA. His achievements include creating a catalog of about 4,000 galaxy clusters and finding a supermassive black hole 12.7 billion light-years from Earth with a mass two billion times that of our Sun.

Ezequiel Treister is a Chandra Postdoctoral Fellow working with David Sanders on active galactic nuclei and galaxy evolution. He received his PhD from the joint University of Chile/Yale program in 2005 working under the supervision of Yale Professor Meg Urry. He arrived at the IfA after spending two years in Chile as a European Southern Observatory fellow and is currently studying the properties of the huge black holes at the centers of galaxies.

David Harrington (PhD, 2008, UH) has stayed on as a postdoctoral fellow “to make use of the excellent observatories this state offers” and to continue developing linear spectropolarimetry as a tool for imaging circumstellar environments. Hawai’i has the only two high-resolution spectropolarimeters on large telescopes in the world, and Harrington is upgrading one of these for use in measuring stellar magnetic fields. He is also helping to adapt the world’s largest curvature adaptive optics system for use with this instrument and improving the SOLARC coronagraphic imaging spectropolarimeter. These instruments will enable new investigations of the near-star environment, stellar magnetism, and solar corona, and also have other applications. Harrington enjoys doing education and outreach as an instructor for the Maui Akamai Internship Program and the Center for Adaptive Optics summer school, and also mentors visiting students and interns in his areas of expertise.

Hubble Fellow Emily Schaller received her PhD in planetary science from the California Institute of Technology in 2008. She studies Kuiper Belt objects and Titan, the largest satellite of Saturn. Her article about the Kuiper Belt object Haumea appears in this issue. While an undergraduate at Dartmouth College, she was a nationally ranked collegiate figure skater.

David Rupke (PhD, 2004, University of Maryland) is a postdoctoral fellow who has come to the IfA to work with Lisa Kewley. His areas of expertise are merging galaxies,
galactic winds, and Fabry-Pérot instrumentation. (Fabry-Pérot interferometers can be used for flexible and sensitive observations of interstellar gas.) Rupke is doing something most postdocs don’t do: he is teaching a section of the basic astronomy course. Getting “back to the basics” and helping people learn about astronomy is something he really enjoys. He and his wife Heidi have a new daughter, Rosie, who in her dad’s eyes is the brightest star in the cosmos.

Mikael Granvik received his PhD in 2008 from the University of Helsinki in his native Finland. He is the Pan-STARRS PS1 MOPS postdoctoral fellow, and he is working with Robert Jedicke and his team that is developing the Moving Object Processing System for the Pan-STARRS project, which will survey the entire available sky several times each month. MOPS is the system that will find near-Earth objects—asteroids and comets—that may pose a threat to our planet. Granvik says, “The most intriguing possibility with an unprecedented survey mission like PS1 is the discovery of completely new types of objects.”

Assistant Astronomer Isabelle Scholl [PhD, 2003, University of Paris VI] came to IfA to work with Shadia Habbal in the field of solar physics. Previously, she worked at the Institute of Space Astrophysics of the National Center for Scientific Research, the French equivalent of the U.S. National Science Foundation. She is an avid photographer who contributed several of her photographs of the 2008 IfA solar eclipse expedition to Nā Kilo Hōkū no. 29.

IfA Director to Receive Highest German Astronomy Award

IfA Director Rolf-Peter Kudritzki will receive the prestigious Karl Schwarzschild Prize for 2009 from the Astronomische Gesellschaft (German Astronomical Society) at its annual meeting in Potsdam, Germany, on September 22. This is the most prestigious award bestowed upon an astronomer in Germany.

As the recipient of the prize, Kudritzki will give the Karl Schwarzschild Lecture at the Astronomische Gesellschaft meeting. His lecture, which will be related to the title of the conference, “Deciphering the Universe through Spectroscopy,” will explain how studying very bright stars in distant galaxies can help us understand both the chemical composition of the galaxies and their distance from us. The lecture will subsequently be published in the journal Astronomische Nachrichten (Astronomical Notes) and in Reviews of Modern Astronomy.

In addition, Kudritzki will give a public lecture in Berlin on September 24 in which he will talk about “Killer Asteroids, Supernovae and the Dark Side of the Universe.” This talk is related to Pan-STARRS, an IfA project that will survey the whole sky for 10 years and find many hitherto undetected objects.

Before becoming director of the IfA in 2000, Kudritzki was an astronomy professor and director of the Munich University Observatory. He is a member of the German National Academy of Sciences and was designated a highly cited author of the Science Citation Index in 2006. His research interests include the study of the largest, hottest stars in our galaxy and beyond.

“I am both surprised and pleased to receive this honor,” said Kudritzki. “Usually, it is given to a non-German astronomer,” he added. Previous recipients of this prize include Nobel Prize winners Riccardo Giacconi, Joseph H. Taylor, Charles H. Townes, and Subrahmanyan Chandrasekhar.

courtesy Rolf-Peter Kudritzki

http://www.astro.rub.de/ag/Auszeichnungen_eng.html
Galileo and the 400th Anniversary of the Telescope

by Bob Joseph

Four hundred years ago, Galileo Galilei looked at the heavens through a small eight-power telescope and initiated an astronomical revolution. He immediately made several surprising discoveries that contributed to the demise of the Earth-centered cosmology of Aristotle and Ptolemy that had dominated Western thought for two millennia. This 400th anniversary of Galileo’s first use of the telescope for astronomy is part of the justification for choosing this year as the International Year of Astronomy.

In 1609, Galileo held the chair of mathematics at the University of Padua, then the leading Italian university. He was 45 years old. He taught astronomy, geometry, and military engineering, had become widely known as a brilliant lecturer, and was famous for his research into the physics of motion.

While visiting Venice (just a few miles from Padua) in July 1609, Galileo heard about an optical instrument that had been invented by a Dutch spectacle-maker, Hans Lippershey. This “Dutch perspective glass” was probably only a three-power telescope. Galileo went back to Padua, worked out the optical theory of a simple two-lens telescope, taught himself how to grind and polish lenses, and by August returned to Venice with an eight-power telescope for the city fathers. The military advantages for the powerful Venetian navy were of course obvious, and they rewarded him by doubling his salary and giving him a lifetime appointment at the university.

Galileo went back to Padua and became the first person to use a telescope for astronomy (except, apparently, for the Englishman Thomas Harriot, who did not publish his telescopic discoveries). Galileo built improved telescopes of 20- and 30-power. By December 1609, he had discovered that the Moon is not the perfectly smooth sphere Aristotle had claimed, but was covered by mountains and craters. He discovered hundreds of new stars in familiar constellations, and most importantly, he discovered the four inner satellites of Jupiter. These made much more plausible the idea advocated 65 years earlier by Nicolas Copernicus (1473–1543) that all the planets orbit the Sun and that the Moon is a satellite of Earth. In contrast, the Earth-centered model had the Moon, the Sun, the planets, and all the stars orbiting the fixed and unmoving Earth once a day.

Galileo saw the scientific significance of these discoveries but also realized that he could use them for personal advancement. He was a great self-promoter, and by March 1610 he had rushed into print a little book describing his discoveries. Meanwhile, he asked the ruling Medici family in Florence for permission to dedicate the book to Cosimo II, then the grand duke of Tuscany, and to name the four moons of Jupiter the Medicean stars (now called the Galilean satellites). This led to a series of fascinating negotiations. The Medici court had a difficult time making a decision, since it was not completely clear that Galileo’s discoveries were genuine. Galileo went to Florence to demonstrate his results, and they finally agreed to Galileo’s dedication. Galileo had also requested an appointment to the Medicean Court, and he was granted the title of chief philosopher and mathematician to the grand duke. In September 1610 he moved to Florence at a salary twice his professorial salary in Padua—and with no teaching responsibilities.

In the autumn of 1610, Galileo made another critical discovery using the telescope: that Venus shows a full range of phases just like those of the Moon. This is simply not possible if both the Sun and Venus orbit Earth, but can be understood the same way the lunar phases are understood if Venus is orbiting the Sun. This was another major argument in his defense of Copernicus’ Sun-centered model of the heavens.

Galileo’s greatest scientific contributions were his research into the theory of motion of projectiles and falling bodies. However, his demonstration of the power of the telescope for penetrating the mysteries of the heavens has dominated the development of astronomy for the past 400 years and continues to do so even today, as groups in both Europe and the United States propose to build optical/infrared telescopes larger than the 10-meter telescopes that currently define the state of the art.
Friends: Real Support for IfA

The Friends of the Institute for Astronomy is a dynamic organization that provides extensive support for astronomy in Hawai‘i. At the beginning of 2009, the International Year of Astronomy, the Friends had over 160 members living on O‘ahu, the neighbor islands, and even the mainland. They are fascinated by astronomy, and want to learn more about it.

The Friends was first organized about ten years ago. In 2006 a small group of dedicated members started meeting quarterly as the Friends Council under the guidance of a new faculty coordinator, Robert Jedicke. This group developed a mission statement: “The Friends of the Institute for Astronomy (IfA) foster community involvement and develop private funding resources in order to support the people, advance the research, promote astronomy education and public outreach, and enhance the activities of the Institute.” The Council developed goals and tasks, and an organization to accomplish this mission. In 2008, the Council added a steering committee composed of Pamela Griffin, Trey McGriff, and Phil Whitney to provide continuity between Council meetings, and IfA added part-time staff support in the form of Events Coordinator Donna Bebber. This year, astronomer Roy Gal also has started to work with the Friends.

The Council has been increasing its support of IfA over the past several years as the number of Friends has grown. Activities include talks by astronomers to public and private groups, financial support for educational programs conducted by IfA graduate students, Friends tours to Mauna Kea and Haleakalā Observatories, writing letters in support of IfA programs, arranging lab tours and star parties for Friends, supporting the annual Mānoa Open House, maintaining a Friends page on the IfA website, providing graduate student research awards, and providing financial support for other activities not included in the IfA budget.

Some of the Friends’ accomplishments include helping to increase attendance at the Frontiers of Astronomy lecture series from 50 to over 300 by developing an email list of almost 1,000 people; arranging and supporting lectures by astronomers to over 5,000 people in Rotary Clubs, college alumni associations, and other community groups; purchasing a van to facilitate graduate student StarLab presentations, talks, and star parties at schools and other venues; providing financial support for relocation of incoming graduate students to UH; and developing a display to recognize major contributors to the IfA.

As 2009 unfolds, the Friends will increase their support for the research and educational efforts of the Institute. IfA activities for the near future include the March 18 Frontiers of Astronomy lecture by renowned IfA astronomer David Jewitt and the annual Mānoa Open House on April 5. To see more events, go to the Friends website at www.ifa.hawaii.edu/friends/activities.html.

You are invited to join the Friends of the IfA, participate in IfA and Friends activities, and provide financial support to IfA. Contact the Friends either by phone (808-956-6665), email [fifa-steeringcommittee@ifa.hawaii.edu], or online [www.ifa.hawaii.edu/friends/application.html].
Modern astronomy is full of stunning surprises. Recently, a team of NASA and university scientists who used two telescopes on Mauna Kea announced that they had conclusively detected the gas methane in the atmosphere of Mars. This is a most exciting discovery because it indicates that Mars is either biologically or geologically active. What makes it even more exciting for me is that the team used the NASA Infrared Telescope Facility (IRTF), a national telescope for solar system research that is managed and operated by the IIA. The other telescope used for this pioneering study is W. M. Keck Telescope, the most powerful telescope on this planet.

Methane, four atoms of hydrogen bound to a carbon atom \([\text{CH}_4]\), is the main component of natural gas on Earth. It is quickly destroyed in the Martian atmosphere by sunlight and other processes, so finding methane means that it is being created or released from deep within Mars now.

Astrobiologists are most interested in this discovery because organisms release much of the methane in Earth’s atmosphere as they digest nutrients. On Earth, scientists have found microorganisms living more than a mile underground in a place where natural radioactivity splits water molecules into molecular hydrogen and oxygen. On Mars, microorganisms may have found similar conditions beneath the surface of the planet.

It is also possible a geologic process produced the Martian methane, either now or long ago. On Earth, the conversion of iron oxide into minerals creates methane, and on Mars this process could result from water, carbon dioxide, and the planet’s internal heat. Although there is no evidence of active volcanism on Mars today, ancient methane trapped in ice cages called clathrates might be released now.

It will take future missions, like NASA’s Mars Science Laboratory, to determine the origin of the Martian methane. But this recent discovery reminds us of the importance of ground-based astronomy to space missions. As my colleague and IRTF division chief, Alan Tokunaga, points out, “This is an excellent example of why the IRTF is funded by NASA for mission support. The discovery of methane in the atmosphere of Mars was unexpected and is generating tremendous interest in the Mars exploration program. I’m certain this will have a major impact on future missions to Mars.”