Exotic Object SDSS1133: Ejected Black Hole or Huge Star?

An international team of researchers analyzing decades of observations has discovered an unusual source of light in a galaxy some 90 million light-years away. They used data taken with many facilities, including the W. M. Keck Observatory on Maunakea and the Pan-STARRS1 telescope on Haleakalā, as well as NASA’s Swift satellite.

Michael Koss, a postdoctoral fellow at the IfA during most of the time the study was ongoing, led the team. IfA astronomer David Sanders and graduate students Yanxia Li and Chao-Ling Hung also participated in the study.

The object's curious properties make it a good match for a supermassive black hole ejected from its home galaxy after merging with another giant black hole. But astronomers can’t yet rule out an alternative possibility. The source, called SDSS1133, may be the remnant of a massive star that underwent a record period of eruptions before destroying itself in a supernova explosion.

"With the data we have in hand, we can’t yet distinguish between these two scenarios," said Koss, now at ETH Zurich, the Swiss Federal Institute of Technology. "One exciting discovery made with NASA’s Swift is that the brightness of SDSS1133 hasn’t changed in ultraviolet light for a decade, which is not something typically seen in a young supernova remnant.”

Koss and colleagues found that the source has brightened significantly during the past six months, a trend that, if maintained, would bolster the black hole interpretation. To analyze the object in greater detail, the team is planning ultraviolet observations with the Cosmic Origins Spectrograph aboard the Hubble Space Telescope in October 2015.

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Refurbishment of the UH Telescopes on Maunakea

by Colin Aspin, Director, UH 2.2-meter telescope, and Louise Good

Built with money from NASA to support its solar system missions and largely funded by NASA for many years, the UH 2.2-meter (88-inch) telescope was the largest telescope on Maunakea, the eighth largest optical telescope in the world, and one of the first professional telescopes controlled by a computer when it became operational in 1970. Now nearly 45 years old, this venerable telescope is in need of major repairs and upgrades if it is going to continue to serve UH faculty and students.

Built on Maunakea in the early 2000s to support the UH Hilo undergraduate astronomy program, the 0.6-meter (24-inch) Hōkū Ke’a (Southern Cross) telescope has never really worked optimally. With the establishment of an undergraduate program at Mānoa, the two campuses have agreed to a joint development plan for both telescopes. Under this plan, undergraduate and graduate students from both campuses will have access to both telescopes.

Recent system failures at the 2.2-meter have included a leaking dome hydraulic drive and the failure of the right ascension (RA) drive. (RA is the astronomical equivalent of longitude on Earth, so that drive enables the telescope to point and track targets around the sky.) Other areas of concern include the dome shutter motors, which must be replaced; the windscreen, which has been nonfunctioning for many years; the declination (latitude) drive, which if not overhauled may fail as the RA drive did; and the mirror covers, which must be replaced. The telescope control software runs on a 1998-vintage Pentium 2 computer and will not run on modern hardware, so an entirely new set of software and hardware must be created. Other work to be done includes purchasing a large-capacity uninterruptible power supply system, painting the dome silver, re-aluminizing the telescope mirrors, installing new (electric) dome drives, repairing the water and electrical systems and the building itself (part of the roof leaks), installing new chillers for the AC system to improve the seeing of the telescope, and Please see Refurbishment of UH Telescopes, pg 2
Whatever SDSS1133 is, it’s persistent. The team was able to detect it in astronomical surveys dating back more than 60 years. The mystery object is part of the dwarf galaxy Markarian 177, located in the bowl of the Big Dipper. Although supermassive black holes usually occupy galactic centers, SDSS1133 is located at least 2,600 light-years from its host galaxy’s core.

The collision and merger of two galaxies disrupt their shapes and result in new episodes of star formation. If each galaxy possesses a central supermassive black hole, the black holes usually form a bound pair at the center of the merged galaxy before ultimately merging into one larger black hole.

Merging black holes release a large amount of energy in the form of gravitational radiation, as explained by Einstein’s theory of gravity. Waves in the fabric of space-time ripple outward in all directions from accelerating masses. If the black holes have unequal masses, the result is a lopsided gravitational wave that kicks the black hole in the opposite direction. Typically, this kick will send the ejected black hole into an elongated orbit around its galaxy. Theoretically, if the kick is strong enough, it may eject the black hole from its home galaxy, fateful it to forever drift through intergalactic space. Astronomers have been searching for such a black hole, but until now have been unable to find one, so if SDSS1133 is the first found, it would be a major discovery.

If SDSS1133 isn’t a black hole, then it must have been a very unusual type of star known as a luminous blue variable (LBV). These stars undergo episodic eruptions that cast large amounts of mass into space long before they explode. Interpreted in this way, SDSS1133 would represent the longest period of LBV eruptions ever observed, followed by a terminal supernova explosion whose light reached Earth in 2001. An interaction between the ejected gas and the explosion’s blast wave could explain the object’s steady brightness in the ultraviolet.

Whether it’s a rogue supermassive black hole or the closing act of a rare star, astronomers have never before seen the likes of SDSS1133.

For more images and videos, see http://svs.gsfc.nasa.gov/cgi-bin/details.cgi?aid=10082

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adding a rotatable tertiary mirror to facilitate instrument changes.

Funding has been acquired to make the necessary repairs and upgrades on both telescopes. The State of Hawai‘i Capital Improvements Project fund has allocated $2.5 million for the work, and UH Mānoa Facilities has promised about $2.5 million in deferred maintenance and capital renewal funds. The UH vice president for research and innovation and the UH Mānoa vice chancellor for research have each allocated $70,000 that IfA matched with money from the UH Foundation Lumb Family Fund.

Astronomer Colin Aspin, the UH 2.2-meter telescope director, has received a four-year NASA grant of $1.6 million to improve the 2.2-meter telescope’s efficiency in recovering near-Earth objects discovered by another UH facility, Pan-STARRS on Haleakalā, Maui. This grant will pay for a new CCD camera (2014), and support 10 percent of the observing time, as well as a post doctoral fellow and a graduate student, for three years (2015–17). Where the funds to support the rest of day-to-day operations of the 2.2-meter telescope will come from is far from clear. The main source of operational funding has been a spectroscopic survey of nearby supernovae, which is now almost complete.

IfA now has a contract with Summit Kinetics, a company based in Waikoloa, Hawai‘i, to create a new telescope control system for the 2.2-meter based on distributed micro-controllers. This should be completed by the summer/fall 2015. Also, plans are in the works to operate the telescope fully robotically, which will increase observational efficiency, since no human interaction will be required.

Plans call for the current Hōkū Ke’a telescope to be replaced by a CDK700 0.7 Meter (28-inch) Observatory Telescope System made by PlaneWave Instruments in a dome made by Ash-Dome that is robust enough to withstand the severe weather conditions atop Maunakea. It is hoped that this telescope will be fully operational in late 2015.
UH Provides Earthquake-Damaged Japanese Observatory with Dome on Haleakalā

A Japanese planetary research observatory was blessed and dedicated September 8 at Haleakalā Observatories in the presence of about 25 scientists and administrators from the United States and Japan.

The new observatory came about because Tohoku University’s Planetary Science Program requested assistance from the UH Institute for Astronomy after the 2011 earthquake damaged its observatory building near Sendai, Japan.

The Institute for Astronomy was able to facilitate the reuse of an existing facility at the Haleakalā Observatories to accept the Tohoku 60-centimeter (24-inch) telescope known as “T60.” The observatory now houses the Japanese instruments and will provide spectacular data on Mars and planetary atmospheres from Haleakalā, which is one of the best observing sites in the world.

Günther Hasinger, director of the IfA, said, “We are excited to enhance an already strong collaboration with the Japanese astronomy community by helping to get their 60-centimeter planetary telescope back on the sky.”

Jeff Kuhn, an IfA Maui scientist, added, “Although this isn’t the largest telescope here, it brings unique instrumental capabilities to Hawai‘i.”

Takahiro Obara, director of the Tohoku Planetary Science Program, also attended the dedication. He noted, “We are extremely pleased to take this next step with our partners at the University of Hawai‘i. We expect that the many Japanese students and scientists that use this instrument will build an even stronger collaboration between the two institutions.”
First Observations of the Surface of Two Oort Cloud Objects

A team led by IfA astronomer Karen Meech has discovered two unusual objects that originate in the Oort Cloud, a spherical halo of comet nuclei in the outer solar system that extends to about 100,000 times the Earth-Sun distance. Although their orbits are like those of Oort-Cloud comets, these objects show almost no comet-like activity, allowing scientists to see their surfaces. These results are particularly intriguing because the objects’ surfaces are different from what astronomers expected, and the objects give them clues about the movement of material in the early solar system as the planets were assembled.

In August 2013, when the Pan STARRS1 survey telescope (PS1) on Haleakalā discovered the first object, C/2013 P2 Pan-STARRS, it looked like an asteroid. “Objects on long-period orbits like this usually exhibit cometary tails, for example cometISON and comet Hale Bopp, so we immediately knew this object was unusual,” explained Meech. “I wondered if this could be the first evidence of movement of solar system building blocks from the inner solar system to the Oort Cloud.”

Follow-up observations in September 2013 with the 8-meter Gemini North telescope on Maunakea hinted at faint, low-level light reflected off a dusty tail. This tail remained through the object’s closest approach to the Sun (2.8 times the Earth-Sun distance, within the outer asteroid belt) in February 2014, but the object didn’t get much brighter. A spectrum of the surface obtained with Gemini North in the spring of 2014 showed that the object was very red, completely different from comet or asteroid surfaces, and more like the surface of an ultra-red Kuiper Belt object. The Kuiper Belt is a region that lies just beyond the orbit of Neptune.

“We had never seen a naked (inactive) Oort Cloud comet, but Jan Oort hypothesized their existence back in 1950 when he inferred the existence of what we now call the Oort Cloud. Oort suggested that these bodies might have a layer of volatile frosting left over from 4.5 billion years of space radiation that disappears after their first pass through the inner solar system. Maybe we are seeing the first evidence of this,” said team member Olivier Hainaut of the European Southern Observatory.

While the team analyzed their observations of comet C/2013 P2 Pan-STARRS, a second object was discovered. C/2014 S3 Pan-STARRS was discovered through the NASA–sponsored Near Earth Object Survey on the PS1 telescope on September 22, 2014. Like C/2013 P2 Pan-STARRS, it also had an Oort Cloud–type cometary orbit and showed minimal activity. To the team’s surprise, follow-up observations with the Canada–France–Hawaii Telescope (CFHT) on Maunakea showed that this object has colors similar to inner solar system asteroids, the first outer solar system object to do so. While the orbit of C/2014 S3 Pan-STARRS took it closer to the Sun than C/2013 P2 (between the asteroid belt and the orbit of Mars), it also barely had a tail.

“I’ll be thrilled if this object turns out to have a surface composition similar to asteroids in the inner part of the asteroid belt. If this is the case, it will be remarkable for a body found so far out in the solar system, especially since it exhibited a tail that may be due to volatile outgassing,” commented Meech. “There are several models that try to explain how the planets grew in the early solar system, and some of these predict that material formed close to the Sun could have been thrown outward into the outer solar system and Oort Cloud, where it remains today. Maybe we are finally seeing that evidence.”

Negative images of C/2013 P2, obtained with the Gemini North 8-meter telescope, and of C/2014 S3, obtained using the CFHT. Both images have been processed to remove most of the background stars and galaxies to enhance the visibility of the faint dust tail. The tail in the left image is the very faint extension toward the 10 o’clock position. In both images, the icy body producing the dust is not resolved, and the central dark region appears larger both because of the effect of telescope optics and because of the dust cloud close to the bodies.
UH Assumes Ownership of United Kingdom Infrared Telescope

The University of Hawai‘i assumed ownership of the United Kingdom Infrared Telescope (UKIRT) on Maunakea on October 31. The UKIRT is one of the world’s leading astronomical infrared observatories, but its funding agency, the Science and Technologies Facilities Council (STFC), announced in 2012 that it could no longer continue to support the telescope in a tightly constrained financial environment.

To save this valuable telescope, which produced more than 200 scientific publications annually, UH has negotiated a scientific cooperation agreement with the University of Arizona and Lockheed Martin Space Technology Advanced Research and Development Laboratories. With funding from NASA and Lockheed Martin, UKIRT, now under the direction of UA staff, will provide new opportunities for research in all areas of astrophysics, but particularly in near-Earth asteroid characterization, studies of forming stars, galaxy evolution, and space debris and its impact on man-made satellites. Initially, only the large infrared camera is being used for the survey work, but the new operators have also started to refurbish and re-commission several of the observatory’s other instruments. UK scientists will continue to provide support of existing data processing and archiving capabilities.

IfA Director Günther Hasinger said, “We are delighted that the UKIRT will continue to produce top quality astronomical research. With a capable new operator and state-of-the-art instrumentation, UKIRT can continue to be a world leader in infrared astronomy for at least 10 more years.”

Meet our 2014 New Graduate Students

**Kelly Blumenthal** grew up in northern New Jersey where despite being sandwiched between two major cities, she managed to cultivate a love for astronomy. She received her BA in astronomy and physics, with a minor in saxophone performance from Boston University. While there, she worked primarily on weak gravitational lensing theory and its implications for the derived local dark matter distribution. When she is not in front of a computer, Kelly is likely either reading a sci-fi novel or teaching herself how to play the ukulele.

**Larissa Nofi** is from San Francisco, California. She received a BS in astrophysics from the University of California, Santa Cruz. Her research there focused primarily on observational astronomy and polarimetry. Prior to coming to the IfA, she worked at UC Santa Cruz as a junior specialist observing stellar remnants, extrasolar planets, and solar system objects at Lick Observatory. She is currently interested in extrasolar planets and ground-based observational astronomy.

**Elizabeth Toller** began her space career at 14 as an intern for the Phoenix Mars Mission. Since then, she has helped test aircraft, taught middle school students to code in the computer language C++, contributed to a high school physics textbook, edited the 2011 annual report of the Space Foundation, and graduated from MIT. She has done research at MIT, the Goddard Space Flight Center, the Jet Propulsion Laboratory, and Lowell Observatory on a wide variety of projects using data gathered with ground-based telescopes and spacecraft.
Meet Our Postdoctoral Fellows

Brian Stalder received his PhD from UH in 2007 and spent about seven years as a postdoc at Harvard before returning to IfA in August as the ATLAS (Asteroid Terrestrial-impact Last Alert System) postdoctoral fellow. While a student at IfA, he studied high-redshift radio galaxies, and he tested detectors and developed prototype cameras as a member of the Pan-STARRS camera group. At Harvard, he continued to work on astronomical instrumentation and on data analysis techniques while studying very large distant galaxy clusters as part of the South Pole Telescope consortium. His duties with the ATLAS project include hardware testing and pipeline development, and he is looking forward to exploring the time-domain of extragalactic sources and searching for near-Earth objects once ATLAS is in operation.

As a near-Earth object postdoctoral fellow, Eva Schunova participates in projects designed to discover and study asteroids and comets near our planet using data obtained by the Pan-STARRS telescopes on Haleakalā in Maui, as well as by other observatories in Hawai’i and around the world. Although she took up this position in September, she is no newcomer to IfA, having spent time here while working on her dissertation for Comenius University in Slovakia and in a variety of short-term positions. Her first name is pronounced like the town ‘Ewa in southwest O’ahu, not like the hurricane, ‘Iwa.

Nicolas Flagey is an expert on interstellar dust and gas, and studies dying stars. He is also interested in data reduction, and instrument and observatory support. After receiving his PhD from Institut d’Astrophysique Spatiale, University Paris XI in France in 2007, he spent several years as a postdoctoral scholar at the California Institute of Technology and the Jet Propulsion Laboratory. Flagey works in the IfA Hilo office and volunteers some of his time to support the Canada-France-Hawaii Telescope on Maunakea. He has the longest title of anyone at IfA, “Hunting for Missing Evolved Stars in the Galactic Plane Postdoctoral Fellow.”

Julien Carron and Melody Wolk are cosmology postdoctoral fellows working with István Szapudi. Carron joined the IfA staff in October 2012 after completing his doctorate at Eidgenössische Technische Hochschule Zürich. He is the recipient of the 2014 Alexander Friedrich Schläfli Prize, given by the Swiss Academy of Natural Sciences for his doctoral thesis, which focused on the spatial distribution of galaxies. His work at IfA includes the large-scale structure of the Universe and weak gravitational lensing. Wolk arrived at IfA in November 2013 after receiving her doctorate from the Institut d’Astrophysique de Paris, where she completed her dissertation under the direction of Henry Joy McCracken and Stephane Colombi. She studies galaxy clustering.
The 2015 IFA poster calendar (17 inches by 22 inches) features the Laniakea Supercluster, which was defined by IFA astronomer Brent Tully and colleagues. Laniakea is a vast area of gravitational attraction that includes our Milky Way and about 100,000 other galaxies. It has a diameter of 160 Mpc, or about 500 million light-years, and contains $10^{17}$ (a 100 quadrillion) times the matter in our Sun. The name Laniakea, which means “immense heaven” in Hawaiian, honors the Polynesian navigators who used their knowledge of the heavens to voyage across the immensity of the Pacific Ocean. Friends of the IFA may pick up a free calendar at IFA offices in Mānoa, on Maui, and in Hilo. For more information about Laniakea, see www.ifa.hawaii.edu/info/press-releases/Laniakea/.
On August 26, I participated in a very significant event organized by the Hawai‘i Island Chamber of Commerce and held at the ‘Imiloa Astronomy Center in Hilo. It celebrated the fiftieth anniversary of astronomy on Maunakea. In the summer of 1964, a road to the summit of Maunakea had been built, and Gerard Kuiper of the Lunar and Planetary Science Laboratory at the University of Arizona and his assistant Alika Herring did the first seeing measurements. After the devastating tsunami of 1960, the use of Maunakea for astronomy had been championed by then Hawai‘i Island Chamber of Commerce Executive Secretary Mitsuo Akiyama and the atmospheric physicist at the Mauna Loa Observatory, Howard Ellis. This was a few years before the Institute for Astronomy was founded in 1967.

Representatives of the families of the three pioneers were present: the Akiyama family, Howard Ellis and his wife, and the daughter and son of Gerard Kuiper. UH President David Lassner made an excellent speech, and Bob McLaren, Don Hall, and I awarded a plaque to each of the pioneers, as well as other gifts. The original plaque will be mounted on the 2.2-meter telescope after its renovation.

The original goal for Alika Herring—a Native Hawaiian—was, to chart the lunar surface in preparation for the Apollo mission, to find a place where the astronauts could land in a bold step that no one had taken before. In that sense, the establishment of Maunakea as an observatory followed the traditions of the Polynesian voyagers, who were the explorers of their time. Now we are preparing a next big step in this tradition, in that our goals reach out to habitable planets around other stars. Facilities like the 30-meter telescope will chart the way and, maybe, in a few hundred years it will be possible for humans to visit an extrasolar planet.

Best wishes for a happy and healthy 2015.