ATST Construction Spurs New Solar Physics Courses

On November 30, the National Solar Observatory (NSO) announced that construction of the Advanced Technology Solar Telescope (ATST) had started on the summit of Haleakalā. The ATST will be the world’s most powerful solar observatory—and a truly revolutionary scientific tool for understanding how variations in the Sun’s output affect Earth’s climate.

Solar astronomers will use ATST to understand what causes solar eruptions and to develop “space weather” forecasting so that the potentially destructive impacts of solar flares and coronal mass ejections on satellites, the power grid, and communication systems can be avoided or lessened.

The National Science Foundation is providing construction funding. About half of this money is from the American Recovery and Reinvestment Act. Construction of the ATST will provide employment for local construction personnel, and when completed, the observatory will offer local high-technology jobs.

IfA Director Günther Hasinger said, “The ATST will lead to tremendous advances in our understanding of the Sun, including those aspects of its variable activity that affect life on Earth.” He thanked all who “worked so hard for many years to make the ATST project a reality,” especially IfA solar astronomers Jeff Kuhn and Haosheng Lin, IfA Associate Director Bob McLaren, former IfA Director Rolf Kudritzki, IfA astronomer Paul Coleman, and IfA Assistant Director for External Relations Mike Maberry.

With the coming of the ATST to Hawai‘i and the UH partnership with the University of Colorado (CU), the New Jersey Institute for Technology (NJIT), and the NSO, solar astronomers at the IfA, led by Kuhn, are working to offer expanded course offerings in solar physics. The inaugural web-enabled course in the George Ellery Hale Collaborative Graduate Education Program in Solar & Space Physics will be “Solar and Stellar Magnetism” taught from CU by Juri Toomre. So far IfA graduate students can only audit these courses, but steps are being taken to allow them to take these courses for credit in the future.

Join us for our upcoming Frontiers public talk entitled “Great Comets: What Makes Them So Great?” on Jan. 31 at 7:30 p.m. Our open house is April 14 from 11:00 a.m. to 4:00 p.m.

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ATST groundbreaking

Distant, Dusty Galaxies

Caitlin Casey, a Hubble Fellow based at IfA, recently led an international group of astronomers who conducted a new census of the brightest, but until now unseen, galaxies in the distant Universe. This work brings astronomers one step closer to understanding how galaxies form and evolve.

These galaxies glow so brightly at infrared wavelengths that they would outshine our own Milky Way by hundreds, maybe thousands, of times. They are forming stars so quickly that 100–500 new stars are born in each galaxy every year, so scientists call them “starbursts.”

Unfortunately, these galaxies are nearly invisible at the wavelengths our eyes, and most telescopes on Earth, can see because they contain huge amounts of dust, which absorbs Please see Galaxy Census pg 2.
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visible starlight. “They were detectable directly in the infrared only from observations of the Herschel Space Observatory. Herschel is an infrared space telescope sensitive to wavelengths not observable from within Earth’s atmosphere,” explained Casey.

Finding these galaxies at visible wavelengths required using the 10-meter Keck telescopes on Mauna Kea, the largest optical telescopes in the world. Over the course of several nights the group was able to detect and measure distances to nearly 800 of these galaxies.

“Detecting these bright infrared galaxies used to be difficult, and a handful was plenty, now with Herschel we are finding them by the thousands, enabling a census like this,” commented Göran Pilbratt, the Herschel Project Scientist at the European Space Agency, which launched Herschel.

“For the first time, we have been able to measure distances, star formation rates, and temperatures for a brand new set of 767 previously unidentified galaxies. The previous similar survey of distant infrared starbursts only covered 73 galaxies. This is a huge improvement,” said Scott Chapman, a co-author on the studies.

“While some of the galaxies are nearby, most are very distant; we even found galaxies that are so far that their light has taken 12 billion years to travel here, so we are seeing them when the Universe was only a ninth of its current age. Now that we have a pretty good idea of how important this type of galaxy is in forming huge numbers of stars in the Universe, the next step is to figure out why and how they formed,” said Casey.

The galaxies might shine so brightly in the infrared as a result of the collision of two spiral-type galaxies, similar to the Milky Way and Andromeda Galaxies. Or they could be so bright because they are in a particularly gas-rich region of space, where galaxies form stars quickly due to constant bombardment from gas and dust. Scientists have been debating these two formation methods for quite some time, but don’t yet have a clear answer.

“It’s hard to figure out how most galaxies formed based on information from only a small part of the Universe, just like it’s hard to guess how big an elephant is if you only get a glimpse of its tail,” Casey said.

“Now that we have an accurate census of starbursting galaxies across a huge time period in the Universe’s history, we can start to piece together how these galaxies grew and evolved.”

Two papers detailing these results have been published in the *Astrophysical Journal*.

http://arxiv.org/abs/1210.4928
http://arxiv.org/abs/1210.4932

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Kuhn explains, “This graduate program is established as a component of the planned move of the headquarters of the NSO to Boulder, Colorado, as we enter the ATST era. Other courses will be taught in turn by UH and NJIT faculty, and we welcome other institutions to join in our attempts to offer a regular and frequent series of courses for graduate students considering research in solar and space physics, or related areas in astrophysics. We are planning for active participation in this inaugural course by scientists from both NSO and the High Altitude Observatory in Boulder.”

On November 9, the Hawaii Board of Land and Natural Resources (BLNR) issued a decision reaffirming the granting of the December 2, 2010, Conservation District Use Permit for the construction of the ATST on Haleakala. This decision cleared the way for the beginning of construction. After the BLNR’s announcement, UH President M.R.C. Greenwood said, “The University is eager to move this $300-million project forward. The Advanced Technology Solar Telescope is important both to the scientific community and to Hawai’i’s economy.”
Astronomers studying the solar system are fortunate. Their targets move, rotate, obscure, and deflect each other on timescales of hours, months, or years, allowing researchers to see them from different angles. Scientists exploring the distant Universe are at a disadvantage in this regard. Most of their targets, such as black holes, galaxies, or clusters of galaxies, are so huge that it takes tens or hundreds of millions of years for an object to present us with a noticeably changed view.

"Being unable to see these large-scale structures from different angles makes it very difficult to figure out their three-dimensional shapes, let alone their relative motions and interactions," explains IfA astronomer Harald Ebeling, an expert on galaxy clusters. "All we see in our images is a 2-D projection of a 3-D structure onto the plane of the sky."

Luckily, when two galaxy clusters collide, astronomers can make use of a clever combination of observations to make the invisible visible. In three recent studies, Ebeling and an international team of collaborators created 3-D models of merging galaxy clusters. Creating these models requires mapping all the components of a cluster: the galaxies that we see in visible light, the hot gas permeating the cluster that emits X-rays, and the invisible dark matter that can be detected only because its gravity distorts the images of objects behind the cluster. To collect all these data, Ebeling’s team used three world-class observatories: the Keck I telescope of the W. M. Keck Observatory, the Chandra X-ray Observatory, and the Hubble Space Telescope.

Although galaxies contribute only a small fraction of the total mass of a galaxy cluster, they constitute crucial test particles that allow scientists to measure the motion of clusters along our line of sight. The final, critical ingredient that permits the reconstruction of the three-dimensional geometry of these cosmic collisions is the measurement of the speed and location of galaxies along the line of sight. These measurements were performed using the Keck I telescope, the largest of its kind in the world.

Gas that is present at very low density throughout the entire Universe becomes concentrated in galaxy clusters, where it is heated to temperatures of millions of degrees, enough to cause it to emit X-rays. The orbiting Chandra X-ray Observatory can measure the distribution and temperature of this hot gas. When clusters collide, scientists can detect crucial clues about the directional motion of the merging cluster, as well as to how close they are to each other in 3-D.

Gravitational lensing causes light rays originating from objects behind a cluster to be bent by the distribution of mass in the cluster “lens.” From the resulting distortions of background galaxies, astronomers can derive highly accurate models of the distribution of dark matter, matter whose presence cannot be seen but can be inferred by the effect it has on visible matter. The extraordinary resolution of the Hubble Space Telescope is critical to detecting the effects of gravitational lensing.

Combining the data to create a credible 3-D model of a complicated system like a merging cluster still involves a lot of physical interpretation. As IfA graduate student Li-Yen Hsu, the lead author of one of the three studies, put it, “It’s a little like solving a jigsaw puzzle with half of the pieces missing.” Eventually, enough pieces of the puzzle were collected to unravel, for instance, the geometry of MACS\$0717.5+3745, a giant triple merger of clusters fed by a filament of dark matter that extends 60 million light-years into space. The team was also able to measure the mass of the entire structure and found that filaments may contain more than half of the mass of the entire Universe.
The Big Island of Hawai‘i is host to a variety of astronomy outreach events coordinated by the Mauna Kea Astronomy Outreach Committee, which includes the IfA. Since most of the observatories are headquartered in Hilo, many of the activities have focused on that side of the island. Seeing the need for better outreach to the Kona side of Hawai‘i Island, the IfA and the Thirty Meter Telescope (TMT) organized a science, technology, engineering, and mathematics (STEM) education workshop in Kona for middle and high school teachers in late October. Nearly a dozen scientists came from the Big Island, IfA Maui, and UH Mānoa to conduct the workshop.

On the evening of October 26, about a dozen teachers and students gathered at Kealakehe High School to learn how to remotely operate the Faulkes Telescope on Haleakalā. The Faulkes Telescope Project is an educational partner of the Las Cumbres Observatory Global Telescope Network. Its aim is to “provide free access to robotic telescopes and a fully supported education program to encourage teachers and students to engage in research-based science education.” IfA Maui Technology Education and Outreach Specialist J.D. Armstrong demonstrated how easy it is to control this two-meter research-grade telescope and take data for classroom projects. Both teachers and students got to choose targets and take their own images. Meanwhile, the West Hawaii Astronomy Club and Mauna Kea Visitor Information Station provided hands-on experience with smaller telescopes and kept attendees’ families entertained.

The next day began with a breakfast and physics education activities for teachers led by Armstrong and IfA Education Specialist Mary Kadooka. Teachers learned about electricity and magnetism and its role in the Sun, and received hands-on experience with spectroscopy and electromagnetism demonstrations and lessons. They also lent the teachers a full kit of electricity, magnetism, and light classroom equipment. At the same time, the teachers’ children were entertained with Lego robotics courtesy of the SUPER-M group. After lunch, we switched it around, and SUPER-M provided math exercises for the teachers while their families built a scale model solar system and experienced the portable StarLab planetarium.

The teachers were beyond enthusiastic and gave the program a huge thumbs up. They felt that they learned a great deal, that they had plenty to take back to their classrooms, and they really appreciated the child care. All of us who led the workshop also had a great time and loved to see the teachers so excited about what we taught them. We will go back to Kona at least once a year to continue this educational program, with more teachers joining us and with new activities.

The workshop was funded by observatory funds, the TMT, an IfA heliophysics grant from NASA, and the UH Mānoa SUPER-M math education team, which is funded by a grant from the National Science Foundation.
Wide Binary Stars: Long-Distance Stellar Relationships

Our Sun is a single star. This puts it in a minority of stars because most stars are binaries—two stars that orbit each other and are bound together by their mutual gravity.

Binaries can be very close, sometimes so close that they actually touch each other. Other pairs are extremely wide, with separations up to a light-year or so.

Astronomers have known about such wide pairs for a long time, but how they form has been a mystery. The problem is that the typical cloud cores out of which stars are born are not large enough to form the widest binaries.

Now IfA astronomer Bo Reipurth and Seppo Mikkola of Tuorla Observatory, University of Turku, Finland, have used computer simulations to come up with a mechanism that accounts for the formation of wide binaries. Most stars are initially formed in small compact multiple systems with two, three, or even more stars at the center of a cloud core. When more than two stars are together in a small space, they gravitationally pull on each other in a chaotic dance, where the lightest body is often kicked out to the outskirts of the core for long periods of time before falling back into the fray.

Meanwhile, the remaining stars feed on the gas at the center of the cloud core and grow heftier. Eventually, the runt of the litter gets such a large kick that it may be completely ejected. But in some cases, the kick is not strong enough for the third body to fully escape, and so it is sent out into a very wide orbit.

The implication is that the widest binaries really should be three stars, not just two stars. Indeed, when astronomers carefully inspect the stars in a very wide system, they often find that one of them is a tight binary. But sometimes it appears that there really are only two stars in a wide system. This means that either wide binaries with only two stars are formed in another way, or something has happened to one of the stars that was once a close binary.

What may have happened is that the stars in the close binary merged into a single larger star. This can happen if there is enough gas in the cloud core to provide resistance to their motion. As the two stars in the close binary move around each other surrounded by gas, they lose energy and spiral toward each other. Sometimes there is so much gas in the core that the two close stars spiral all the way in and collide with each other in a spectacular merging explosion.

The nearest wide binary to us is Alpha Centauri, which is so similar to the Sun that it is almost a twin. Alpha Centauri is actually a close binary, but it also has a small distant companion called Proxima Centauri that is currently about 15,000 times the Earth-Sun distance, or about a quarter of a light-year, away. Several billions of years ago, all three stars were born close together, before a violent event sent Proxima out into its wide orbit, where it has been moving ever since.

The paper by Reipurth and Mikkola about the formation of the widest binaries has been published in the journal Nature.
Scientific Views of the Threats to Humanity
by Louise Good

The pre-Halloween Frontiers of Astronomy Community Event held on October 23 was not for scaredy-cats. No, it wasn’t the presence of ghosts, goblins, or zombies that was scary. It is the dangers faced by our planet and the human race that could give you nightmares.

“It’s Not a Zombie Apocalypse: Scientific Views of Threats to Humanity” began with astronomer Karen Meech giving a brief history—past and future—of our planet. She explained that we live in an era when Earth is neither too hot nor too cold for complex life, including humans, but that this will not last for more than another half a billion years.

Next, Larry Denneau, a software engineer with the Pan-STARRS project, spoke about the possibility of a sizable asteroid hitting Earth. There are about 650,000 known asteroids. Of these, about 9,000 qualify as near-Earth asteroids, and of these 1,300 are “potentially hazardous.” But with Pan-STARRS and other observing programs searching the heavens for these asteroids, we may be able to find those on a collision course with Earth in time to deflect them. It is believed that a large asteroid caused the demise of the dinosaurs about 65 million years ago, but as the saying goes, “The dinosaurs did not have a space program.” Besides, the demise of the dinosaurs ultimately resulted in the rise of mammals, so in a real sense we may owe our existence to that asteroid.

Mike Mottl, a professor in the UH Oceanography Department, spoke about supervolcanoes and something called large igneous provinces (LIPs). He said that the volcano under Yellowstone National Park is potentially the most dangerous on Earth. The 1980 eruption of Mount St. Helens in Washington state blew 1.2 cubic kilometers of pulverized rock into the air. Previous Yellowstone eruptions have spewed hundreds or thousands of cubic kilometers of material into the air. An LIP is a large deposit (more than 100,000 square kilometers) of igneous rocks that is connected to a hotspot, a stationary region in which hot mantle rises to the surface, much like the hotspot that has made the Hawaiian Islands, only much, much larger. LIPs release huge amounts of lava in a very short geological time, resulting in rises in sea level, seawater temperature, and the temperature of Earth’s atmosphere, thereby causing mass extinctions. Fortunately, the eruption of a supervolcano or an LIP does not appear to be imminent.

Rich Gazan of the UH Information and Computer Sciences Department discussed the threat from technology in which people will choose to live a virtual life through technology rather than face life’s real challenges. He sees it starting to happen, with people spending more and more time interacting with screens (television, video games, the Internet, etc.) than with other humans. He fears that humanity will willingly transform itself into components of a massive biotechnological computer matrix that generates and experiences its own stories, because real life is too hard.

It got scarier: Biochemist Steve Freeland spoke about the exponential rise in population that has occurred in the last century. So far, our gains in technology have enabled us to raise enough food to prevent widespread famine, but that may not last. There is a good chance that we will exhaust the resources of our planet. He said that one bright spot is that the education and empowerment of women brings down the birth rate and the level of violence in the world.

But the scariest moment came when Mottl replied to a question: He said that the consequences of global warming have consistently been underestimated by scientists and that there is now evidence that the limit of carbon dioxide that Earth can absorb will be reached in 16 years. Reaching this limit could trigger what Mottl calls “irreversible feedbacks,” causing Earth to become significantly warmer, making it unlivable for a significant percentage of its already-huge human population.
UH Astrobiology Workshop for Beijing Teachers

Last August, professional astronomers from throughout the world gathered at the International Astronomical Union (IAU) General Assembly in Beijing, China. As part of the activities related to this meeting, Bin Yang, a UH NASA Astrobiology Institute (NAI) postdoctoral fellow, and IfA Education Specialist Mary Kadooka organized a two-day workshop at the Beijing Planetarium for about 40 middle school geography teachers from Beijing, where the geography curriculum includes a month of astronomy.

Held at the Beijing Planetarium, the program consisted of lectures and activities led by astronomers from China, Taiwan, Japan, Portugal, and the United States. The first morning, after the participants were welcomed by Jin Zhu, planetarium director, IfA astronomer and UH NAI principal investigator Karen Meech presented an introduction to astrobiology, IfA postdoctoral fellow Henry Hsieh spoke about main-belt comets, and Yang explained Kepler’s law for orbits. After lunch, Shinsuke Abe of the National Central University (NCU) in Taiwan explained the Hayabusa mission to the asteroid Itokawa, and Kadooka led an activity about Kepler’s laws and the orbits of planets.

The second day featured lectures by Wing-Huen Ip (NCU) on the detection of exoplanets, by Nader Haghighipour [IfA and UH NAI] on the habitability of exoplanets, and by Biwei Jiang (Beijing Normal University) on stellar evolution. Yang led an activity about the transits of exoplanets, and Rosa Doran [Interactive Astronomy Nuclei, Portugal] led an activity about black holes.

The teachers enjoyed using actual Mars images to plot the orbit of Mars with paper and pencil. They worked with exoplanet transits to find the distance between the exoplanets and their stars using Kepler’s law of periods. They also learned about calculating the mass of a black hole using SalsaJ software, an activity of the European Union Hands On Universe curriculum, sponsored by the European Space Agency.

The lectures and related activities in English were translated into Chinese prior to and during the workshop. Yang and Donglu Chen of the Beijing Planetarium served as translators for presenters who do not speak Chinese.

Educators from Great Britain and a scientist from South Africa who is interested in outreach also attended the workshop.

The next IAU General Assembly will be held in Honolulu in August 2015. “Working with international astronomers in Beijing was helpful for planning outreach for that meeting,” Kadooka said.
From the Director

This has been a busy and successful year at the IfA. We hired a new tenure-track faculty member, Andrew Howard. A visiting committee of outside astronomers had a fruitful stay that produced a variety of recommendations to strengthen and improve all aspects of the IfA. We made significant progress on developing an astrophysics/astronomy undergraduate program, including the debut of a two-semester course, Foundations of Astrophysics, and had positive discussions about starting a School of Astronomy. Our fundraising activities are yielding positive results.

Plans to build three new telescopes here in Hawai‘i are coming to fruition. Construction of the Advanced Technology Solar Telescope and the Pan-STARRS PS2 telescope has begun on Haleakalā, and a hearing officer has recommended to the Department of Land and Natural Resources that the conservation district use permit required to build the Thirty Meter Telescope on Mauna Kea be granted. At the same time, the PS1 mission has been extended to run together with that of PS2, which is now on sound financial footing.

Our research programs have continued to prosper, from the discovery of a potentially habitable planet around a relatively nearby star to mapping the brightest galaxies in the Universe. Our scientists wrote and published over 200 scholarly articles during 2012 and also continue to create new optical and infrared instruments and sensors that are used on some of the premier telescopes on Earth and in space.

Our public education and outreach activities have also continued to grow—we participated in nearly 200 events during 2012. Among these, the Venus transit outreach program reached about 20,000 people at our events around the state, we initiated a new K–12 teacher education workshop in Kona [see page 4], and a workshop for Chinese middle school teachers was held in conjunction with the International Astronomical Union General Assembly in Beijing, China [see page 7]. Please join us for the next Frontiers of Astronomy Event, “Great Comets: What Makes Them So Great?” on January 31 and at our Mānoa Open House on April 14.

I wish you a happy and healthy new year!