Astronomers are the equivalent of anti-farmers: like farmers, we depend on the weather for our livelihood but, unlike real farmers, we normally hope for continuous clear skies and extended drought conditions. Lately, in northeastern Kansas, the farmers are coming out ahead in the weather column. As noted in last months newsletter, May 1 was supposed to be the start of a new era in the history of Astronomy Associates with the transition of public observing to a permanent site at the Baker Wetlands Discovery Center. The advantages are numerous and the long-term hope is that establishing a permanent site for the club will benefit both AAL and the Discovery Center, drawing more visitors to the site during regular hours and establishing a consistent schedule and location for observing which doesn’t need to shift every couple of years. Unfortunately, the entire few days leading up to and including the night of the opening event were cloud covered and/or populated by thunderstorms. We have rescheduled the special observing event, open to the public, at the Baker Wetlands Discovery Center for SUNDAY MAY 15, starting at 8:30 pm. Club members are STRONGLY encouraged to bring their scopes to this event to help kick off our partnership with the Wetlands Discovery Center. If the response on Facebook (Continued on page 2)
About the Astronomy Associates of Lawrence

The club is open to all people interested in sharing their love for astronomy. Monthly meetings are typically on the second Friday of each month and often feature guest speakers, presentations by club members, and a chance to exchange amateur astronomy tips. Approximately the last Sunday of each month we have an open house at the Prairie Park Nature Center. Periodic star parties are scheduled as well. For more information, please contact the club officers: president, Rick Heschmeyer at rcjbm@sbcglobal.net; webmaster, Howard Edin, at howard@howardedin.com; AlCor William Winkler, at billwink10@yahoo.com; or faculty advisor, Prof. Bruce Twarog at btwarog@ku.edu. Because of the flexibility of the schedule due to holidays and alternate events, it is always best to check the Web site for the exact Fridays and Sundays when events are scheduled. The information about AAL can be found at http://www.physics.ku.edu/AAL/

Copies of the Celestial Mechanic can also be found on the web at http://www.physics.ku.edu/AAL/newsletter
"Russian Doll" Galaxy Clusters Reveal Information About Dark Energy

Astronomers have used data from NASA's Chandra X-ray Observatory, ESA's Planck and a large list of optical telescopes to develop a powerful new method for investigating dark energy, the mysterious energy that is currently driving the accelerating expansion of the universe.

The technique takes advantage of the observation that the outer reaches of galaxy clusters, the largest structures in the universe held together by gravity, show similarity in their X-ray emission profiles and sizes. More massive clusters are simply scaled up versions of less massive ones.

"In this sense, galaxy clusters are like Russian dolls, with smaller ones having a similar shape to the larger ones," said Andrea Morandi of the University of Alabama at Huntsville, who led the study. "Knowing this lets us compare them and accurately determine their distances across billions of light years."

By using these galaxy clusters as distance markers, astronomers can measure how quickly the Universe was expanding at different times since the Big Bang. According to Einstein's theory of general relativity, the rate of expansion is determined by the properties of dark energy plus the amount of matter in the Universe, where the latter is mostly made up of unseen material called dark matter.

If the assumed cosmological parameters (e.g., the properties of dark energy or dark matter) are incorrect, then distant clusters will not appear to be similar, that is their sizes will be larger or smaller than expected. The cosmological parameters are then adjusted so that all of the different clusters, with different masses and different distances, appear to be similar. The process is akin to determining the unknown weight of an object by adding or subtracting known weights to a balance scale until the two sides balance.

These latest results confirm earlier studies that the properties of dark energy have not changed over billions of years. They also support the idea that dark energy is best explained by the "cosmological constant," which Einstein first proposed and is equivalent to the energy of empty space.

"Although we've looked hard at other explanations," said co-author Ming Sun, also of the University of Alabama at Huntsville, "it still appears that dark energy behaves just like Einstein's cosmological constant."

The researchers studied 320 galaxy clusters with distances from Earth that ranged from about 760 million light years to about 8.7 billion light years. This spans the era where dark energy (Continued on page 8)
Hubble Shatters The Cosmic Record For Most Distant Galaxy

By Ethan Siegel

The farther away you look in the distant universe, the harder it is to see what's out there. This isn't simply because more distant objects appear fainter, although that's true. It isn't because the universe is expanding, and so the light has farther to go before it reaches you, although that's true, too. The reality is that if you built the largest optical telescope you could imagine -- even one that was the size of an entire planet -- you still wouldn't see the new cosmic record-holder that Hubble just discovered: galaxy GN-z11, whose light traveled for 13.4 billion years, or 97% the age of the universe, before finally reaching our eyes.

There were two special coincidences that had to line up for Hubble to find this: one was a remarkable technical achievement, while the other was pure luck. By extending Hubble's vision away from the ultraviolet and optical and into the infrared, past 800 nanometers all the way out to 1.6 microns, Hubble became sensitive to light that was severely stretched and redshifted by the expansion of the universe. The most energetic light that hot, young, newly forming stars produce is the Lyman-α line, which is produced at an ultraviolet wavelength of just 121.567 nanometers. But at high redshifts, that line passed not just into the visible but all the way through to the infrared, and for the newly discovered galaxy, GN-z11, its whopping redshift of 11.1 pushed that line all the way out to 1471 nanometers, more than double the limit of visible light!

Hubble itself did the follow-up spectroscopic observations to confirm the existence of this galaxy, but it also got lucky: the only reason this light was visible is because the region of space between this galaxy and our eyes is mostly ionized, which isn't true of most locations in the universe at this early time! A redshift of 11.1 corresponds to just 400 million years after the Big Bang, and the hot radiation from young stars doesn't ionize the majority of the universe until 550 million years have passed. In most directions, this galaxy would be invisible, as the neutral gas would block this light, the same way the light from the center of our galaxy is blocked by the dust lanes in the galactic plane. To see farther back, to the universe's first true galaxies, it will take the James Webb Space Telescope. Webb's infrared eyes are much less sensitive to the light-extinction caused by neutral gas than instruments like Hubble. Webb may reach back to a redshift of 15 or even 20 or more, and discover the true answer to one of the universe's greatest mysteries: when the first galaxies came into existence!
Behemoth Black Hole Found in an Unlikely Place

Astronomers have uncovered a near-record-breaking supermassive black hole, weighing 17 billion suns, in an unlikely place: in the center of a galaxy in a sparsely populated area of the universe. The observations, made by NASA's Hubble Space Telescope and the Gemini telescope in Hawaii, could indicate that these monster objects may be more common than once thought. Until now, the biggest supermassive black holes — those roughly 10 billion times the mass of our sun — have been found at the cores of very large galaxies in regions of the universe packed with other large galaxies. In fact, the current record holder tips the scale at 21 billion suns and resides in the crowded Coma galaxy cluster, which consists of over 1,000 galaxies.

The newly discovered supersized black hole resides in the center of a massive elliptical galaxy, NGC 1600, located in a cosmic backwater, a small grouping of 20 or so galaxies,” said lead discoverer Chung-Pei Ma, a University of California-Berkeley astronomer and head of the MASSIVE Survey, a study of the most massive galaxies and supermassive black holes in the local universe. While finding a gigantic black hole in a massive galaxy in a crowded area of the universe is to be expected — like running across a skyscraper in Manhattan — it seemed less likely they could be found in the universe’s small towns.

“There are quite a few galaxies the size of NGC 1600 that reside in average-size galaxy groups,” Ma said. “We estimate that these smaller groups are about 50 times more abundant than spectacular galaxy clusters like the Coma cluster. So the question now is, ‘Is this the tip of an iceberg?’ Maybe there are more monster black holes out there that don’t live in a skyscraper in Manhattan, but in a tall building somewhere in the Midwestern plains.”

The researchers also were surprised to discover that the black hole is 10 times more massive than they had predicted for a galaxy of this mass. Based on previous Hubble surveys of black holes, astronomers had developed a correlation between a black hole’s mass and the mass of its host galaxy’s central bulge of stars — the larger the galaxy bulge, the proportionally more massive the black hole. But for galaxy NGC 1600, the giant black hole’s mass far overshadows the mass of its relatively sparse bulge. “It appears that that relation does not work very well with extremely massive black holes; they are a larger fraction of the host galaxy’s mass,” Ma said.

Ma and her colleagues are reporting the discovery of the black hole, which is located about 200 million light-years from Earth in the direction of the constellation Eridanus, in the April 6 issue of the journal Nature. Jens Thomas of the Max Planck Institute for Extraterrestrial Physics, Garching, Germany, is the paper’s lead author.

One idea to explain the black hole’s monster size is that it merged with another black hole long ago when galaxy interactions were more frequent. When two galaxies merge, their central black holes settle into the core of the new galaxy and orbit each other. Stars falling near the binary black hole, depending on their speed and trajectory, can actually rob momentum from the whirling pair and pick up enough velocity to escape from the galaxy’s core. This gravitational interaction causes the black holes to slowly move closer together, eventually merging to form an even larger black hole. The supermassive black hole then continues to grow by gobbling up gas funneled to the core by galaxy collisions. “To become this massive, the black hole would have had a very voracious phase during which it devoured lots of gas,” Ma said. The frequent meals consumed by NGC 1600 may also be the reason why the galaxy resides in a small town, with few galactic neighbors. NGC 1600 is the most dominant galaxy in its galactic group, at least three times brighter than its neighbors. “Other groups like this rarely have such a large luminosity gap between the brightest and the second brightest galaxies,” Ma said. Most of the galaxy’s gas was consumed long ago when the black hole blazed as a

This computer-simulated image shows a supermassive black hole at the core of a galaxy. The black region in the center represents the black hole’s event horizon, where no light can escape the massive object’s gravitational grip. The black hole’s powerful gravity distorts space around it like a funhouse mirror. Light from background stars is stretched and smeared as the stars skim by the black hole.
Light Echoes Give Clues to Protoplanetary Disk

Imagine you want to measure the size of a room, but it's completely dark. If you shout, you can tell if the space you're in is relatively big or small, depending on how long it takes to hear the echo after it bounces off the wall. Astronomers use this principle to study objects so distant they can't be seen as more than points. In particular, researchers are interested in calculating how far young stars are from the inner edge of their surrounding protoplanetary disks. These disks of gas and dust are sites where planets form over the course of millions of years.

"Understanding protoplanetary disks can help us understand some of the mysteries about exoplanets, the planets in solar systems outside our own," said Huan Meng, postdoctoral research associate at the University of Arizona, Tucson. "We want to know how planets form and why we find large planets called 'hot Jupiters' close to their stars."

Meng is the first author on a new study published in the Astrophysical Journal using data from NASA's Spitzer Space Telescope and four ground-based telescopes to determine the distance from a star to the inner rim of its surrounding protoplanetary disk.

Making the measurement wasn't as simple as laying a ruler on top of a photograph. Doing so would be as impossible as using a satellite photo of your computer screen to measure the width of the period at the end of this sentence.

Instead, researchers used a method called "photo-reverberation," also known as "light echoes." When the central star brightens, some of the light hits the surrounding disk, causing a delayed "echo." Scientists measured the time it took for light coming directly from the star to reach Earth, then waited for its echo to arrive.

Thanks to Albert Einstein's theory of special relativity, we know that light travels at a constant speed. To determine a given distance, astronomers can multiply the speed of light by the time light takes to get from one point to another.

To take advantage of this formula, scientists needed to find a star with variable emission -- that is, a star that emits radiation in an unpredictable, uneven manner. Our own sun has a fairly stable emission, but a variable star would have unique, detectable changes in radiation that could be used for picking up corresponding light echoes. Young stars, which have variable emission, are the best candidates.

The star used in this study is called YLW 16B and lies about 400 light-years from Earth. YLW 16B has about the same mass as our sun, but at one million years old, it's just a baby compared to our 4.6-billion-year-old home star.

Astronomers combined Spitzer data with observations from ground-based telescopes: the Mayall telescope at Kitt Peak National Observatory in Arizona; the SOAR and SMARTS telescopes in Chile; and the Harold L. Johnson telescope in Mexico. During two nights of observation, researchers saw consistent time lags between the stellar emissions and their echoes in the surrounding disk.

The ground-based observatories detected the shorter-wavelength infrared light emitted directly from the star, and

(Continued on page 8)
A Space Spider Watches Over Young Stars

A nebula known as "the Spider" glows fluorescent green in an infrared image from NASA's Spitzer Space Telescope and the Two Micron All Sky Survey (2MASS). The Spider, officially named IC 417, lies near a much smaller object called NGC 1931, not pictured in the image. Together, the two are called "The Spider and the Fly" nebulae. Nebulae are clouds of interstellar gas and dust where stars can form.

The Spider, located about 10,000 light-years from Earth in the constellation Auriga, is clearly a site of star formation. It resides in the outer part of the Milky Way, almost exactly in the opposite direction from the galactic center. A group of students, teachers and scientists focused their attention on this region as part of the NASA/IPAC Teacher Archive Research Program (NITARP) in 2015. They worked on identifying new stars in this area.

One of the largest clusters of young stars in the Spider can be seen easily in the image. Toward the right of center, against the black background of space, you can see a bright group of stars called "Stock 8." The light from this cluster carves out a bowl in the nearby dust clouds, seen in the image as green fluff. Along the sinuous tail in the center, and to the left, the groupings of red point sources clumped in the green are also young stars.

In the image, infrared wavelengths, which are invisible to the unaided eye, have been assigned visible colors. Light with a wavelength of 1.2 microns, detected by 2MASS, is shown in blue. The Spitzer wavelengths of 3.6 and 4.5 microns are green and red, respectively.

---

The Future of Space Astronomy: The Golden Mirrors of the James Webb Space Telescope

The golden mirrors of NASA's Names Webb Space Telescope are seen in this image inside the clean room at the space agency's Goddard Space Flight Center. The space telescope is undergoing testing ahead of its 2018 launch. Each of the James Webb Space Telescope's mirror segments are about the size of a coffee table and weighs 46 pounds (20 kilograms).
Spitzer observed the longer-wavelength infrared light from the disk's echo. Because of thick interstellar clouds that block the view from Earth, astronomers could not use visible light to monitor the star. Researchers then calculated how far this light must have traveled during that time lag: about 0.08 astronomical units, which is approximately 8 percent of the distance between Earth and its sun, or one-quarter the diameter of Mercury's orbit. This was slightly smaller than previous estimates with indirect techniques, but consistent with theoretical expectations.

Although this method did not directly measure the height of the disk, researchers were able to determine that the inner edge is relatively thick. Previously, astronomers had used the light echo technique to measure the size of accretion disks of material around supermassive black holes. Since no light escapes from a black hole, researchers compare light from the inner edge of the accretion disk to light from the outer edge to determine the disk size. This technique is also used to measure the distance to other features near the accretion disk, such as dust and the surrounding fast-moving gas.

While light echoes from supermassive black holes represent delays of days to weeks, scientists measured the light echo from the protoplanetary disk in this study to be a mere 74 seconds. The Spitzer study marks the first time the light echo method was used in the context of protoplanetary disks.

"This new approach can be used for other young stars with planets in the process of forming in a disk around them," said Peter Plavchan, co-author of the study and assistant professor at Missouri State University in Springfield.

The researchers will need more Hubble observations to make accurate measurements to determine if the moon's orbit is elliptical or circular. Preliminary estimates indicate that if the moon is in a circular orbit, it completes a circuit around Makemake in 12 days or longer.

Determining the shape of the moon's orbit will help settle the question of its origin. A tight circular orbit means that MK 2 is probably the product of a collision between Makemake and another Kuiper Belt Object. If the moon is in a wide, elongated orbit, it is more likely to be a captured object from the Kuiper Belt. Either event would have likely occurred several billion years ago, when the solar system was young.

The discovery may have solved one mystery about Makemake. Previous infrared studies of the dwarf planet revealed that while Makemake's surface is almost entirely bright and very cold, some areas appear warmer than other areas. Astronomers had suggested that this discrepancy may be due to the sun warming discrete dark patches on Makemake's surface. However, unless Makemake is in a special orientation, these dark patches should make the dwarf planet's brightness vary substantially as it rotates. But this amount of variability has never been observed.

These previous infrared data did not have sufficient resolution to separate Makemake from MK 2. The team's reanalysis, based on the new Hubble observations, suggests that much of the warmer surface detected previously in infrared light may, in reality, simply have been the dark surface of the companion MK 2. There are several possibilities that could explain why the moon would have charcoal-black surface, even though it is orbiting a dwarf planet that is as bright as fresh snow. One idea is that, unlike larger objects such as Makemake, MK 2 is small enough that it cannot gravitationally hold onto a bright, icy crust, which sublimates, changing from solid to gas, under sunlight. This would make the moon similar to comets and other Kuiper Belt Objects, many of which are covered with very dark material.

When Pluto's moon Charon was discovered in 1978, astronomers quickly calculated the mass of the system. Pluto's mass was hundreds of times smaller than the mass originally estimated when it was found in 1930. With Charon's discovery, astronomers suddenly knew something was fundamentally different about Pluto. "That's the kind of transformative measurement that having a satellite can enable," Parker said.
Hubble Discovers Moon Orbiting the Dwarf Planet Makemake

Peering to the outskirts of our solar system, NASA's Hubble Space Telescope has spotted a small, dark moon orbiting Makemake, the second brightest icy dwarf planet — after Pluto — in the Kuiper Belt. The moon — provisionally designated S/2015 (136472) 1 and nicknamed MK 2 — is more than 1,300 times fainter than Makemake. MK 2 was seen approximately 13,000 miles from the dwarf planet, and its diameter is estimated to be 100 miles across. Makemake is 870 miles wide. The dwarf planet, discovered in 2005, is named for a creation deity of the Rapa Nui people of Easter Island.

The Kuiper Belt is a vast reservoir of leftover frozen material from the construction of our solar system 4.5 billion years ago and home to several dwarf planets. Some of these worlds have known satellites, but this is the first discovery of a companion object to Makemake. Makemake is one of five dwarf planets recognized by the International Astronomical Union. The observations were made in April 2015 with Hubble's Wide Field Camera 3. Hubble's unique ability to see faint objects near bright ones, together with its sharp resolution, allowed astronomers to pluck out the moon from Makemake's glare. The discovery was announced today in a Minor Planet Electronic Circular.

The observing team used the same Hubble technique to observe the moon as they did for finding the small satellites of Pluto in 2005, 2011, and 2012. Several previous searches around Makemake had turned up empty. "Our preliminary estimates show that the moon's orbit seems to be edge-on, and that means that often when you look at the system you are going to miss the moon because it gets lost in the bright glare of Makemake," said Alex Parker of the Southwest Research Institute, Boulder, Colorado, who led the image analysis for the observations.

A moon's discovery can provide valuable information on the dwarf-planet system. By measuring the moon's orbit, astronomers can calculate a mass for the system and gain insight into its evolution. Uncovering the moon also reinforces the idea that most dwarf planets have satellites. "Makemake is in the class of rare Pluto-like objects, so finding a companion is important," Parker said. "The discovery of this moon has given us an opportunity to study Makemake in far greater detail than we ever would have been able to without the companion."

Finding this moon only increases the parallels between Pluto and Makemake. Both objects are already known to be covered in frozen methane. As was done with Pluto, further study of the satellite will easily reveal the density of Makemake, a key result that will indicate if the bulk compositions of Pluto and Makemake are also similar. "This new discovery opens a new chapter in comparative planetology in the outer solar system," said team leader Marc Buie of the Southwest Research Institute, Boulder, Colorado.

(Continued on page 8)
Hubble Sees a Star 'Inflating' a Giant Bubble

Twenty-six candles grace NASA's Hubble Space Telescope's birthday cake this year, and now one giant space "balloon" will add to the festivities. Just in time for the 26th anniversary of Hubble's launch on April 24, 1990, the telescope has photographed an enormous, balloon-like bubble being blown into space by a super-hot, massive star. Astronomers trained the iconic telescope on this colorful feature, called the Bubble Nebula, or NGC 7635. The bubble is 7 light-years across — about one-and-a-half times the distance from our sun to its nearest stellar neighbor, Alpha Centauri. The Bubble Nebula lies 7,100 light-years from Earth in the constellation Cassiopeia.

(Continued from page 5)