## COMING EVENTS

### PUBLIC OBSERVING
**WETLANDS DISCOVERY CENTER**
**SUNDAY, MAY 01**
**8:00 PM**

### PUBLIC LECTURE
**MONDAY APRIL 18**
**7:30 PM Woodruff Auditorium**
Dr. Brian Fields
**WHEN STARS ATTACK!**

### PUBLIC OBSERVING
**Transit of Mercury**
**Monday, MAY 09**
**Sunrise—2PM**
Roof—Parking Garage South of Lawrence Public Library

**President**
Rick Heschmeyer
rcjbm@sbcglobal.net

**ALCOR**
William Winkler
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### Of Local Interest

#### 2016 Transit of Mercury

On Monday, 2016 May 09, Mercury will transit the Sun for the first time since 2006. The transit or passage of a planet across the face of the Sun is a relatively rare occurrence. Two planets – Venus and Mercury – have orbits that lie inside Earth’s orbit of the Sun. When one of these planets passes between the Earth and the Sun it is called an inferior conjunction. When this alignment of Earth, and either Mercury or Venus is nearly perfect, we can observe Mercury or Venus as they move across the face of the Sun. This is called a transit.

Because the planets have slightly different orbital planes, transits do not occur every time there is an inferior conjunction. The last two transits of Venus were in 2004 and 2012. The next two will not be until 2117 and 2125. Mercury, however, transits more frequently. The last two transits of Mercury were in 2003 and 2006. The next two are on May 9, 2016 and November 11, 2019. As seen from Earth, only transits of Mercury and Venus are possible. There are approximately 13 transits of Mercury each century. In comparison, transits of Venus occur in pairs with more than a century separating each pair.

The principal events occurring during a transit are conveniently characterized by contacts, analogous to the contacts of an annular solar eclipse. The transit begins with contact I, which is the instant when the planet's disk is externally tangent to the Sun. Shortly after contact I, the planet can be seen as a small notch along the solar limb. The entire disk of the planet is first seen at contact II when the planet is internally tangent to the Sun. During the next several hours, the silhouetted planet slowly traverses the brilliant solar disk. At contact III, the planet reaches the opposite limb and once again is internally tangent to the Sun. Finally, the transit ends at contact IV when the planet's limb is externally tangent to the Sun. Contacts I and II define the phase called ingress while contacts III and IV are known as egress. Position angles

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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 Wetlands Discovery Center. Periodic star parties are scheduled as well. For more information, please contact the club officers: president, Rick Heschmeyer at rcbm@sbcglobal.net; webmaster, Howard Edin, at howard@howardedin.com; AI Cor 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
Peering deep into the heart of our Milky Way galaxy, NASA’s Hubble Space Telescope reveals a rich tapestry of more than half a million stars. Except for a few blue, foreground stars, the stars are part of the Milky Way’s nuclear star cluster, the most massive and densest star cluster in our galaxy. So packed with stars, it is equivalent to having a million suns crammed into the volume of space between us and our closest stellar neighbor, Alpha Centauri, 4.3 light-years away. At the very hub of our galaxy, this star cluster surrounds the Milky Way’s central supermassive black hole, which is about 4 million times the mass of our sun. Astronomers used Hubble’s infrared vision to pierce through the dust in the disk of our galaxy that obscures the star cluster. In this image, scientists translated the infrared light, which is invisible to human eyes, into colors our eyes can see. The red stars are either embedded or shrouded by intervening dust. Extremely dense clouds of gas and dust are seen in silhouette, appearing dark against the bright background stars. These clouds are so thick that even Hubble’s infrared capability could not penetrate them. Hubble’s sharp vision allowed astronomers to measure the movements of the stars over four years. Using this information, scientists were able to infer important properties such as the mass and structure of the nuclear star cluster. The motion of the stars may also offer a glimpse into how the star cluster was formed — whether it was built up over time by globular star clusters that happen to fall into the galaxy’s center, or from gas spiraling in from the Milky Way’s disk to form stars at the core.

This picture, spanning 50 light-years across, is a mosaic stitched from nine separate images from Hubble’s Wide Field Camera 3. The center of the Milky Way is located 27,000 light-years away. The “snowstorm” of stars in the image is just the tip of the iceberg: Astronomers estimate that about 10 million stars in this cluster are too faint to be captured in this image.
Gravitational Wave Astronomy Will Be The Next Great Scientific Frontier

By Ethan Siegel

Imagine a world very different from our own: permanently shrouded in clouds, where the sky was never seen. Never had anyone see the Sun, the Moon, the stars or planets, until one night, a single bright object shone through. Imagine that you saw not only a bright point of light against a dark backdrop of sky, but that you could see a banded structure, a ringed system around it and perhaps even a bright satellite: a moon. That's the magnitude of what LIGO (the Laser Interferometer Gravitational-wave Observatory) saw, when it directly detected gravitational waves for the first time.

An unavoidable prediction of Einstein's General Relativity, gravitational waves emerge whenever a mass gets accelerated. For most systems -- like Earth orbiting the Sun -- the waves are so weak that it would take many times the age of the Universe to notice. But when very massive objects orbit at very short distances, the orbits decay noticeably and rapidly, producing potentially observable gravitational waves. Systems such as the binary pulsar PSR B1913+16 [the subtlety here is that binary pulsars may contain a single neutron star, so it's best to be specific], where two neutron stars orbit one another at very short distances, had previously shown this phenomenon of orbital decay, but gravitational waves had never been directly detected until now.

When a gravitational wave passes through an objects, it simultaneously stretches and compresses space along mutually perpendicular directions: first horizontally, then vertically, in an oscillating fashion. The LIGO detectors work by splitting a laser beam into perpendicular "arms," letting the beams reflect back and forth in each arm hundreds of times (for an effective path lengths of hundreds of km), and then recombining them at a photodetector. The interference pattern seen there will shift, predictably, if gravitational waves pass through and change the effective path lengths of the arms. Over a span of 20 milliseconds on September 14, 2015, both LIGO detectors (in Louisiana and Washington) saw identical stretching-and-compressing patterns. From that tiny amount of data, scientists were able to conclude that two black holes, of 36 and 29 solar masses apiece, merged together, emitting 5% of their total mass into gravitational wave energy, via Einstein's \( E = mc^2 \).

During that event, more energy was emitted in gravitational waves than by all the stars in the observable Universe combined. The entire Earth was compressed by less than the width of a proton during this event, yet thanks to LIGO's incredible precision, we were able to detect it. At least a handful of these events are expected every year. In the future, different observatories, such as NANOGrav (which uses radiotelescopes to the delay caused by gravitational waves on pulsar radiation) and the space mission LISA will detect gravitational waves from supermassive black holes and many other sources. We've just seen our first event using a new type of astronomy, and can now test black holes and gravity like never before.

Observation of Gravitational Waves from a Binary Black Hole Merger B. P. Abbott et al., (LIGO Scientific Collaboration and Virgo Collaboration), Physical Review Letters 116, 061102 (2016). This figure shows the data (top panels) at the Washington and Louisiana LIGO stations, the predicted signal from Einstein's theory (middle panels), and the inferred signals (bottom panels). The signals matched perfectly in both detectors.
When Stars Attack!
In Search of Near-Earth Supernova Explosions

Brian Fields
University of Illinois,
Urbana-Champaign

Monday, April 18, 2016
7:30 p.m.
Woodruff Auditorium
Kansas Union
1301 Jayhawk Blvd.
Lawrence, KS 66045

The most massive stars are the celebrities of the cosmos: they are very rare, but live extravagantly and die in a spectacular and violent supernova explosions. While these events are awesome to observe, they can take a more sinister shade when they occur closer to home, because an explosion inside a certain "minimum safe distance" would pose a grave threat to Earthlings. We will discuss these cosmic insults to life, and ways to determine whether a supernova occurred nearby over the course of the Earth's existence. We will then present recent evidence that a star exploded near the Earth about 3 million years ago. Radioactive iron atoms have been found in ancient samples of deep-ocean material, and are likely to be debris from this explosion. These data the first time allow sea sediments to be used as a telescope, probing the nuclear fires that power exploding stars. Furthermore, an explosion so close to Earth was probably a "near-miss," which emitted intense and possibly harmful radiation.

About Professor Brian Fields:
Brian Fields is a professor of Astronomy and of Physics at the University of Illinois, and the Astronomy department Chair. His PhD is from the University of Chicago, and he has been at Illinois since 1998. Prof. Fields is fascinated by the "inner space/outer space" connections that link the science at the smallest and largest scales. His research focuses on the highest-energy sites in nature—the big bang, exploding stars (supernovae), and high-energy particles in space (cosmic rays).

Department of Physics and Astronomy Public Event
For more information: http://physics.ku.edu 785-864-4626 physics@ku.edu
NASA's Spitzer Maps Climate Patterns on a Super-Earth
Observations from NASA's Spitzer Space Telescope have led to the first temperature map of a super-Earth planet -- a rocky planet nearly two times as big as ours. The map reveals extreme temperature swings from one side of the planet to the other, and hints that a possible reason for this is the presence of lava flows.

"Our view of this planet keeps evolving," said Brice Olivier Demory of the University of Cambridge, England, lead author of a new report appearing in the March 30 issue of the journal Nature. "The latest findings tell us the planet has hot nights and significantly hotter days. This indicates the planet inefficiently transports heat around the planet. We propose this could be explained by an atmosphere that would exist only on the day side of the planet, or by lava flows at the planet surface."

The toasty super-Earth 55 Cancri e is relatively close to Earth at 40 light-years away. It orbits very close to its star, whipping around it every 18 hours. Because of the planet's proximity to the star, it is tidally locked by gravity just as our moon is to Earth. That means one side of 55 Cancri, referred to as the day side, is always cooking under the intense heat of its star, while the night side remains in the dark and is much cooler.

"Spitzer observed the phases of 55 Cancri e, similar to the phases of the moon as seen from the Earth. We were able to observe the first, last quarters, new and full phases of this small exoplanet," said Demory. "In return, these observations helped us build a map of the planet. This map informs us which regions are hot on the planet."

Spitzer stared at the planet with its infrared vision for a total of 80 hours, watching it orbit all the way around its star multiple times. These data allowed scientists to map temperature changes across the entire planet. To their surprise, they found a dramatic temperature difference of 2,340 degrees Fahrenheit (1,300 Kelvin) from one side of the planet to the other. The hottest side is nearly 4,400 degrees Fahrenheit (2,700 Kelvin), and the coolest is 2,060 degrees Fahrenheit (1,400 Kelvin).

The fact Spitzer found the night side to be significantly colder than the day side means heat is not being distributed around the planet very well. The data argues against the notion that a thick atmosphere and winds are moving heat around the planet as previously thought. Instead, the findings suggest a planet devoid of a massive atmosphere, and possibly hint at a lava world where the lava would become hardened on the night side and unable to transport heat.

(Continued on page 8)
Hubble Unveils Monster Stars

An international team of astronomers using the ultraviolet capabilities of NASA’s Hubble Space Telescope has identified nine monster stars with masses over 100 times the mass of the sun in the star cluster R136. This makes for the largest sample of very massive stars identified to date. The results, which will be published in the Monthly Notices of the Royal Astronomical Society, raise many new questions about the formation of massive stars. R136 is only a few light-years across and is located in the Tarantula Nebula within the Large Magellanic Cloud, about 170,000 light-years away from Earth. The young cluster hosts many extremely massive, hot, and luminous stars whose energy is mostly radiated in the ultraviolet.

The image shows the central region of the Tarantula Nebula in the Large Magellanic Cloud. The young and dense star cluster R136 can be seen at the lower right of the image. This cluster contains hundreds of young, blue stars, among them the most massive stars detected in the universe so far. Astronomers using NASA’s Hubble Space Telescope were able to conduct a detailed imaging and spectroscopic study of the central and most dense region of this cluster. Here they found nine stars with masses greater than 100 times the mass of the sun. The cluster is located 170,000 light-years away from Earth.
"The day side could possibly have rivers of lava and big pools of extremely hot magma, but we think the night side would have solidified lava flows like those found in Hawaii," said Michael Gillon, University of Liège, Belgium.

The Spitzer data also revealed the hottest spot on the planet has shifted over a bit from where it was expected to be: directly under the blazing star. This shift either indicates some degree of heat recirculation confined to the day side, or points to surface features with extremely high temperatures, such as lava flows.

Additional observations, including from NASA’s upcoming James Webb Space Telescope, will help to confirm the true nature of 55 Cancri e.

The new Spitzer observations of 55 Cancri are more detailed thanks to the telescope’s increased sensitivity to exoplanets. Over the past several years, scientists and engineers have figured out new ways to enhance Spitzer’s ability to measure changes in the brightness of exoplanet systems. One method involves precisely characterizing Spitzer’s detectors, specifically measuring “the sweet spot” -- a single pixel on the detector -- which was determined to be optimal for exoplanet studies.

“By understanding the characteristics of the instrument -- and using novel calibration techniques of a small region of a single pixel -- we are attempting to eke out every bit of science possible from a detector that was not designed for this type of high-precision observation,” said Jessica Krick of NASA’s Spitzer Space Science Center, at the California Institute of Technology in Pasadena.

“Our spectroscopic observations reveal the galaxy to be even farther away than we had originally thought, right at the distance limit of what Hubble can observe,” said Gabriel Brammer of STScI, second author of the study.

Before astronomers determined the distance for GN-z11, the most distant galaxy measured spectroscopically had a redshift of 8.68 (13.2 billion years in the past). Now, the team has confirmed GN-z11 to be at a redshift of 11.1, nearly 200 million years closer to the Big Bang. “This is an extraordinary accomplishment for Hubble. It managed to beat all the previous distance records held for years by much larger ground-based telescopes,” said investigator Pieter van Dokkum of Yale University. “This new record will likely stand until the launch of the James Webb Space Telescope.”

The combination of Hubble’s and Spitzer’s imaging reveals that GN-z11 is 25 times smaller than the Milky Way and has just one percent of our galaxy’s mass in stars. However, the newborn GN-z11 is growing fast, forming stars at a rate about 20 times greater than our galaxy does today. This makes an extremely remote galaxy bright enough for astronomers to find and perform detailed observations with both Hubble and Spitzer.

The results reveal surprising new clues about the nature of the very early universe. “It’s amazing that a galaxy so massive existed only 200 million to 300 million years after the very first stars started to form. It takes really fast growth, producing stars at a huge rate, to have formed a galaxy that is a billion solar masses so soon,” explained investigator Garth Illingworth of the University of California, Santa Cruz.

These findings provide a tantalizing preview of the observations that the James Webb Space Telescope will perform after it is launched into space in 2018. “Hubble and Spitzer are already reaching into Webb territory,” Oesch said. “This new discovery shows that the Webb telescope will surely find many such young galaxies reaching back to when the first galaxies were forming,” added Illingworth. This discovery also has important consequences for NASA’s planned Wide-Field Infrared Survey Telescope (WFIRST), which will have the ability to find thousands of such bright, very distant galaxies.

The result implies that Type Ia supernovas are either all caused by white dwarf collisions, or are caused by a mixture of white dwarf collisions and the mechanism where the white dwarf pulls material from a companion star.

“It is important to identify the trigger mechanism for Type Ia supernovas because if there is more than one cause, then the contribution from each may change over time,” said Harvard’s Alicia Soderberg, another co-author on the study. This means astronomers might have to recalibrate some of the ways we use them as ‘standard candles’ in cosmology.”

The team also derived a new estimate for the age of the supernova remnant of about 110 years, younger than previous estimates of about 150 years.

More progress on understanding the trigger mechanism should come from studying Type Ia supernovas in nearby galaxies, using the increased sensitivity provided by a recent upgrade to the VLA.
Hubble Team Breaks Cosmic Distance Record

By pushing NASA’s Hubble Space Telescope to its limits, an international team of astronomers has shattered the cosmic distance record by measuring the farthest galaxy ever seen in the universe. This surprisingly bright infant galaxy, named GN-z11, is seen as it was 13.4 billion years in the past, just 400 million years after the Big Bang. GN-z11 is located in the direction of the constellation of Ursa Major.

“We’ve taken a major step back in time, beyond what we’d ever expected to be able to do with Hubble. We see GN-z11 at a time when the universe was only three percent of its current age,” explained principal investigator Pascal Oesch of Yale University. The team includes scientists from Yale University, the Space Telescope Science Institute (STScI), and the University of California.

Astronomers are closing in on the first galaxies that formed in the universe. The new Hubble observations take astronomers into a realm that was once thought to be only reachable with NASA’s upcoming James Webb Space Telescope.

This measurement provides strong evidence that some unusual and unexpectedly bright galaxies found earlier in Hubble images are really at extraordinary distances. Previously, the team had estimated GN-z11’s distance by determining its color through imaging with Hubble and NASA’s Spitzer Space Telescope. Now, for the first time for a galaxy at such an extreme distance, the team used Hubble’s Wide Field Camera 3 to precisely measure the distance to GN-z11 spectroscopically by splitting the light into its component colors.

Astronomers measure large distances by determining the “redshift” of a galaxy. This phenomenon is a result of the expansion of the universe; every distant object in the universe appears to be receding from us because its light is stretched to longer, redder wavelengths as it travels through expanding space to reach our telescopes. The greater the redshift, the farther the galaxy.

(Continued on page 8)
Trigger for Milky Way's Youngest Supernova Identified

Scientists have used data from NASA's Chandra X-ray Observatory and the NSF's Jansky Very Large Array to determine the likely trigger for the most recent supernova in the Milky Way. They applied a new technique that could have implications for understanding other Type Ia supernovas, a class of stellar explosions that scientists use to determine the expansion rate of the Universe.

Astronomers had previously identified G1.9+0.3 as the remnant of the most recent supernova in our Galaxy. It is estimated to have occurred about 110 years ago in a dusty region of the Galaxy that blocked visible light from reaching Earth.

G1.9+0.3 belongs to the Type Ia category, an important class of supernovas exhibiting reliable patterns in their brightness that make them valuable tools for measuring the rate at which the Universe is expanding.

"Astronomers use Type Ia supernovas as distance markers across the Universe, which helped us discover that its expansion was accelerating," said Sayan Chakraborti, who led the study at Harvard University. "If there are any differences in how these supernovas explode and the amount of light they produce, that could have an impact on our understanding of this expansion."

Most scientists agree that Type Ia supernovas occur when white dwarfs, the dense remnants of Sun-like stars that have run out of fuel, explode. However, there has been a debate over what triggers these white dwarf explosions. Two primary ideas are the accumulation of material onto a white dwarf from a companion star or the violent merger of two white dwarfs.

The new research with archival Chandra and VLA data examines how the expanding supernova remnant G1.0+0.3 interacts with the gas and dust surrounding the explosion. The resulting radio and X-ray emission provide clues as to the cause of the explosion. In particular, an increase in X-ray and radio brightness of the supernova remnant with time, according to theoretical work by Chakraborti's team, is expected only if a white dwarf merger took place.

"We observed that the X-ray and radio brightness increased with time, so the data point strongly to a collision between two white dwarfs as being the trigger for the supernova explosion in G1.9+0.3," said co-author Francesca

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