The month of October proved to be both busy and surprisingly cooperative, weatherwise. Our Oct. meeting was given over to an evening filled with astronomical insight and happy cub scouts, followed by observing on the Wescoe beach. One week later, the skies cleared just in time for a lovely view of the partial solar eclipse from the parking lot of the Lied Center. There was a great turnout with a variety of viewing options, from Coronado solar scopes to sunspotter projections (above) to a colander projection (below). Everyone enjoyed themselves and the temperatures stayed warm and comfortable. Finally, on Sun. we had public observing on a clear and dark (except for the parking lot lights) evening at Prairie Park. While the Royals were losing, Bill Wachspress showed an appreciative pair of the public the sights of the celestial sphere for October. Many thanks to all the club members who gave their time, effort, and equipment in support of each of the events. While time consuming, they are a critical component in keeping astronomy and the club in the public consciousness. Well Done!

And, if you thought October was busy, the calendar of potential events for November is even fuller. First, for AAL, we have our monthly meeting on Friday, Nov. 21 (poster, pg. 5). Our speaker is San Diego State University astronomer Dr. Paul Etzel, who will be discussing stellar evolution. Paul is a native Kansan who attended KU and Washburn (he now serves on their advisory board), and has been instrumental in the development of the Mt. Laguna Observatory 1.25m with KU. (If you’re wondering, our normal mid-month meeting is moved back one week to avoid the opening game of the KU basketball season.)

Next, to avoid Thanksgiving weekend, our next public observing session is Sunday, Dec. 7 at 7:30 PM at Prairie Park Nature Center.

For non-AAL events, the Friends of Chamber Music and Linda Hall Library of Science and Technology is presenting an exciting multi-media program call *The Galileo Project* with Tafelmusik Baroque Orchestra on Sunday November 9 at 2 p.m. at the Folly Theater. In addition, there will be a pre-concert lecture and an exhibit at intermission. For details and ticket costs, go to http://www.chambermusic.org/. On Nov. 11, Astronaut Chris Hadfield will be visiting KC and Linda Hall Library (see poster on pg. 2). If interested, it is recommended that you call for tickets quickly.

At KU, on Fri. Nov. 21, there are two linked events: *The Big Bang in the Laboratory* (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/celestialmechanic

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(Continued from page 1)

1:30-2:30 pm and Excavating the Universe: Physics Interacts with the Arts 2:30-4:00 pm in The Commons. The events are sponsored by the Spencer Museum of Art and the Department of Physics & Astronomy. The early event is a talk by Paolo Giubellino, an experimental physicist at CERN in charge of the ALICE experiment, while the later event is a roundtable discussion that brings together artists and physicists to talk about the ways their work is stimulated and inspired by the other discipline.

Any suggestions for improving the club or the newsletter are always welcome.

"Good morning, Earth."

Meet Astronaut Chris Hadfield
Engineer, Author, Musician, and Social Media Guru

November 11, 2014
5:00 p.m.
Linda Hall Library

As the first Canadian to walk in space, Chris Hadfield is described by Forbes magazine as "perhaps the most social media savvy astronaut ever to leave Earth." The Linda Hall Library Foundation is offering an exclusive private book signing to meet the former Space Shuttle Astronaut & International Space Station Commander prior to his lecture at Unity Temple.

By supporting Linda Hall Library Foundation’s Annual Fund at the suggested contribution of $50, you will receive:

♦ two tickets to an exclusive reception with Chris Hadfield at the Linda Hall Library
♦ a copy of Commander Hadfield's book “You Are Here: Around the World in 92 Minutes” personally signed by the author

Space is limited for this exclusive event so register today! Photos will be permitted.
For more information contact Kate Haugen at events@lindahall.org or 816-926-8792.

“Good morning, Earth.” is how Colonel Chris Hadfield—writing on Twitter—woke up the world every day while living aboard the International Space Station for over five months.

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Galactic Wheel of Life Shines in Infrared

It might look like a spoked wheel or even a “Chakram” weapon wielded by warriors like “Xena,” from the fictional TV show, but this ringed galaxy is actually a vast place of stellar life. A newly released image from NASA’s Spitzer Space Telescope shows the galaxy NGC 1291. Though the galaxy is quite old, roughly 12 billion years, it is marked by an unusual ring where newborn stars are igniting.

“The rest of the galaxy is done maturing,” said Kartik Sheth of the National Radio Astronomy Observatory of Charlottesville, Virginia. “But the outer ring is just now starting to light up with stars.”

NGC 1291 is located about 33 million light-years away in the constellation Eridanus. It is what’s known as a barred galaxy, because its central region is dominated by a long bar of stars (in the new image, the bar is within the blue circle and looks like the letter “S”).

The bar formed early in the history of the galaxy. It churns material around, forcing stars and gas from their original circular orbits into large, non-circular, radial orbits. This creates resonances -- areas where gas is compressed and triggered to form new stars. Our own Milky Way galaxy has a bar, though not as prominent as the one in NGC 1291.

Sheth and his colleagues are busy trying to better understand how bars of stars like these shape the destinies of galaxies. In a program called Spitzer Survey of Stellar Structure in Galaxies, or S4G, Sheth and his team of scientists are analyzing the structures of more than 3,000 galaxies in our local neighborhood. The farthest galaxy of the bunch lies about 120 million light-years away -- practically a stone’s throw in comparison to the vastness of space.

The astronomers are documenting structural features, including bars. They want to know how many of the local galaxies have bars, as well as the environmental conditions in a galaxy that might influence the formation and structure of bars.

"Now, with Spitzer we can measure the precise shape and distribution of matter within the bar structures," said Sheth. "The bars are a natural product of cosmic evolution, and they are part of the galaxies’ endoskeleton. Examining this endoskeleton for the fossilized clues to their past gives us a unique view of their evolution."

In the Spitzer image, shorter-wavelength infrared light has been assigned the color blue, and longer-wavelength light, red. The stars that appear blue in the central, bulge region of the galaxy are older; most of the gas, or star-making fuel, was previously used up by earlier generations of stars. When galaxies are young and gas-rich, stellar bars drive gas toward the center, feeding star formation.

(Continued on page 10)
Where does the sun’s energy come from?
Every 1.5 millionths of a second, the sun releases more energy than all humans consume in an entire year. Its heat influences the environments of all the planets, dwarf planets, moons, asteroids, and comets in our solar system.

And that light travels far out into the cosmos—just one star among billions and billions.

Create a ‘solar wind’ that pushes against the fabric of interstellar space billions of miles away.

Allows gases and liquids to exist on many planets and moons, and causes icy comets to form fiery halos.

Powers the chemical reactions that make life possible on Earth.

That Heat...

The energy travels outward through a large area called the convective zone. Then it travels outward to the photosphere, where it emits heat, charged particles, and light.

How does a big ball of hydrogen create all that heat? The short answer is that it is big. If it were smaller, it would be just a sphere of hydrogen, like Jupiter. But the sun is much bigger than Jupiter. It would take 433,333 Jupiters to fill it up!

That's a lot of hydrogen. That means it’s held together by a whole lot of gravity. And THAT means there is a whole lot of pressure inside of it. There is so much pressure that the hydrogen atoms collide with enough force that they literally melt into a new element—helium.

This process—called nuclear fusion—releases energy while creating a chain reaction that allows it to occur over and over and over again. That energy builds up. It gets as hot as 15 million degrees Fahrenheit in the sun's core.

Nuclear Fusion

For more articles, games, and activities, visit spaceplace.nasa.gov
FRIDAY NOV. 21, 2014
2001 Malott
7:30 PM

Free and Open to the Public
Close Encounters: Comet Siding Spring Seen Next to Mars

This composite Hubble Space Telescope image captures the positions of Comet Siding Spring and Mars in a never-before-seen close passage of a comet by the Red Planet, which happened at 2:28 p.m. EDT October 19, 2014. On that date the comet passed by Mars at approximately 87,000 miles (about one-third the distance between Earth and the Moon). At that time, the comet and Mars were approximately 149 million miles from Earth.

The comet image shown here is a composite of NASA Hubble Space Telescope exposures taken between October 18, 8:06 a.m. EDT and October 19, 11:17 p.m. EDT. Hubble took a separate photograph of Mars at 10:37 p.m. EDT on October 18.

The Mars and comet images have been added together to create a single picture to illustrate the angular separation between the comet and Mars at closest approach. The separation is approximately 1.5 arcminutes, or 1/20th of the angular diameter of the full Moon. The background starfield in this composite image is synthesized from ground-based telescope data provided by the Palomar Digital Sky Survey, which has been reprocessed to approximate Hubble's resolution. The solid, icy comet nucleus is too small to be resolved in the Hubble picture. The comet's bright coma, a diffuse cloud of dust enshrouding the nucleus, and a dusty tail, are clearly visible.

This is a composite image because a single exposure of the stellar background, Comet Siding Spring, and Mars would be problematic. Mars is actually 10,000 times brighter than the comet, and so could not be properly exposed to show detail in the Red Planet. The comet and Mars were also moving with respect to each other and so could not be imaged simultaneously in one exposure without one of the objects being motion blurred. Hubble had to be programmed to track on the comet and Mars separately in two different observations.

The images were taken with Hubble's Wide Field Camera 3.
Slow-Growing Galaxies Offer Window to Early Universe

What makes one rose bush blossom with flowers, while another remains barren? Astronomers ask a similar question of galaxies, wondering how some flourish with star formation and others barely bloom.

A new study published in the Oct. 16 issue of the journal Nature addresses this question by making some of the most accurate measurements yet of the meager rates at which small, sluggish galaxies create stars. The report uses data from the European Space Agency’s Herschel mission, in which NASA is a partner, and NASA’s Spitzer Space Telescope and Galaxy Evolution Explorer (GALEX).

The findings are helping researchers figure out how the very first stars in our universe sprouted. Like the stars examined in the new study, the first-ever stars from billions of years ago took root in poor conditions. Growing stars in the early cosmos is like trying to germinate flower seeds in a bed of dry, poor soil. Back then, the universe hadn't had time yet to make "heavy metals," elements heavier than hydrogen and helium.

"The metals in space help act in some ways like a fertilizer to help stars grow," said George Helou, an author of the new study and director of NASA's Infrared Processing and Analysis Center (IPAC) at the California Institute of Technology, Pasadena. The lead author of the study is Yong Shi, who performed some of the research at IPAC before moving to Nanjing University in China.

The two slow-going galaxies in the study, called Sextans A and ESO 146-G14, lack in heavy metals, just like our young and remote cosmos, only they are a lot closer to us and easier to see. Sextans A is located about 4.5 million light-years from Earth in the Sextans constellation.

The environment in this galaxy is similar to that of our infant universe because it lacks in heavy metals, or elements heavier than hydrogen and helium. Heavy metals act in some ways like fertilizers for stars, helping them form and grow. Scientists study galaxies like Sextans A to learn how stars still manage to slowly bloom under these poor-growing conditions. The research provides a better understanding of how the very first stars in our universe came to be.

In this image, the purple shows gas; blue shows young stars and the orange and yellow dots are newly formed stars heating up dust. (Continued on page 10)
Suspected Black Hole Unmasked as Ultraluminous Pulsar

An Ultraluminous X-ray Source (ULX) that astronomers had thought was a black hole is really the brightest pulsar ever recorded. ULXs are objects that produce more X-rays than most “normal” X-ray binary systems, in which a star is orbiting a neutron star or a stellar-mass black hole. Black holes in these X-ray binary systems generally weigh about five to thirty times the mass of the sun.

Astronomers used NASA’s NuSTAR (Nuclear Spectroscopic Telescope Array) and Chandra X-ray Observatory to study two ULXs in the center of M82, a galaxy located just over 11 million light years from Earth. This composite image shows X-rays from NuSTAR (purple) and Chandra (blue) that have been combined with optical data from the NRAO 2.1-meter telescope (gold). The extended X-ray emission is unrelated to the two ULXs.

Until now, astronomers have thought that matter falling onto black holes powered the bright X-ray emission in all ULXs. Most of the black holes in ULXs are thought to weigh at least 10 to 50 times the mass of the sun, but some of the brightest ULXs are thought to weigh 100 times the sun’s mass, or more.

The new X-ray data provide a critical clue to the nature of one of the ULXs in M82. Using NuSTAR, scientists have discovered regular variations, or “pulsations,” in the object known as M82X-2. This object pulses once on average every 1.37 seconds, and pulsations change in a regular pattern with a period of 2.5 days.

These types of pulsations are not seen with black holes. Rather, they are the signatures of so-called pulsars, rapidly rotating neutron stars. The apparent shifts in the pulsation period are due to the motion of the star in its orbit. Assuming that the pulsar weighs 1.4 times the mass of the sun (the common size of a pulsar or neutron star), the data imply that the companion star’s mass is at least 5.2 times the mass of the sun.

This discovery is significant because it may mean that pulsars make up a significant part of the ULX population. Chandra had observed M82X-2 before but these pulsations were not found until observations were made by NuSTAR, a high-energy X-ray mission that was launched in 2012. While NuSTAR detected the pulsations, Chandra, with its excellent spatial resolution, was needed to resolve M82X-2 from the other nearby ULX and rule out the contributions from other possible sources unresolved by NuSTAR. Although Chandra did not detect pulsations from M82X-2, scientists determined which source was responsible for the pulsations seen by NuSTAR by comparing the Chandra and NuSTAR images.

In addition to the pulsations, the overall brightness in X-rays of M82X-2 is variable over timescales lasting weeks and months. At its brightest it is more than ten times brighter than any known pulsar that is powered by accretion of material from a companion star. It is so bright that generally astronomers thought that only 50 to 100 solar mass black holes could explain such a bright ULX.

The latest study of M82X-2 provides new challenges for theorists to develop models explaining how a pulsar can

(Continued on page 10)
NASA's Hubble Telescope Finds Potential Kuiper Belt Targets for New Horizons Pluto Mission

Peering out to the dim, outer reaches of our solar system, NASA's Hubble Space Telescope has uncovered three Kuiper Belt objects (KBOs) the agency's New Horizons spacecraft could potentially visit after it flies by Pluto in July 2015.

The KBOs were detected through a dedicated Hubble observing program by a New Horizons search team that was awarded telescope time for this purpose.

"This has been a very challenging search, and it's great that in the end Hubble could accomplish a detection — one NASA mission helping another," said Alan Stern of the Southwest Research Institute (SwRI) in Boulder, Colorado, principal investigator of the New Horizons mission.

The Kuiper Belt is a vast rim of primordial debris encircling our solar system. KBOs belong to a unique class of solar system objects that has never been visited by spacecraft and which contain clues to the origin of our solar system.

The KBOs that Hubble found are each about 10 times larger than typical comets, but only about 1-2 percent of the size of Pluto. Unlike asteroids, KBOs have not been heated by the Sun, and are thought to represent a pristine, well preserved, deep-freeze sample of what the outer solar system was like following its birth 4.6 billion years ago. The KBOs found in the Hubble data are thought to be the building blocks of dwarf planets such as Pluto.

The New Horizons team started to look for suitable KBOs in 2011 using some of the largest ground-based telescopes on Earth. They found several dozen KBOs, but none were reachable within the fuel supply available aboard the New Horizons spacecraft.

"We started to get worried that we could not find anything suitable, even with Hubble, but in the end the space telescope came to the rescue," said New Horizons science team member John Spencer of SwRI. "There was a huge sigh of relief when we found suitable KBOs; we are 'over the moon' about this detection."

Following an initial proof of concept of the Hubble pilot observing program in June, the New Horizons team was awarded telescope time by the Space Telescope Science Institute for a wider survey in July. When the search was completed in early September, the team identified one KBO that is "definitely reachable" and two other potentially accessible KBOs that will require more tracking over several months to know whether they too are accessible by the New Horizons spacecraft.

This was a needle-in-a-haystack search for the New Horizons team because the elusive KBOs are extremely small, faint, and difficult to pick out against myriad background stars in the constellation Sagittarius, which is in the present direction of Pluto. The three KBOs identified are each a whopping 1 billion miles beyond Pluto. Two of the KBOs are estimated to be as large as 34 miles (55 kilometers) across, and the third is perhaps as small as 15 miles (25 kilometers).

The New Horizons spacecraft, launched in 2006 from Florida, is the first mission in NASA's New Frontiers Program. Once a NASA mission completes its prime mission, the agency conducts an extensive science and technical review to determine whether extended operations are warranted.

The New Horizons team expects to submit such a proposal to NASA in late 2016 for an extended mission to fly by one of the newly identified KBOs. Hurting across the solar system, the New Horizons spacecraft would reach the distance of 4 billion miles from the Sun roughly three to four years after its July 2015 Pluto encounter. Accomplishing such a KBO flyby would substantially increase the science return from the New Horizons mission as laid out by the 2003 Planetary Science Decadal Survey.
Herschel data, captured at the longest infrared wavelengths of light, let the researchers see the cool dust in which stars are buried. The dust serves as a proxy for the total amount of gas in the region—the basic ingredient of stars. To other telescopes, this dust is cold and invisible. Herschel, on the other hand, can pick up its feeble glow.

Supporting radio-wavelength measurements of some of the gas in the galaxies came from the National Radio Astronomy Observatory's Jansky Very Large Array observatory near Socorro, New Mexico, and the Australia Telescope Compact Array observatory, near Narrabri.

Meanwhile, archived data from Spitzer and GALEX were used to look at the rate of star formation. Spitzer sees shorter-wavelength infrared light, which comes from dust that is warmed by new stars. GALEX images capture ultraviolet light from the shining stars themselves.

Putting all these pieces together enabled the astronomers to determine that the galaxies are plodding along, creating stars at rates 10 times lower than their normal counterparts.

"Star formation is very inefficient in these environments," said Shi. "Extremely metal-poor nearby galaxies are the best way to know what went on billions of years ago."

The heavy metals in present-day galaxies help star formation to flourish through cooling effects. For a star to form, a ball of gas needs to fall in on itself with the help of its own gravity. Ultimately, the material has to become dense enough for atoms to fuse and ignite, creating starlight. But as this cloud collapses, it heats up and puffs back out again, counteracting the process. Heavy metals cool everything down by radiating away the heat, enabling the cloud to condense into a star.

How stars in the early universe were able to do this without the cooling benefits of heavy metals remains unknown. Studies like this shine light on the very first stellar buds, giving us a glimpse into the roots of our cosmic history.