Report from the Officers
The first meeting of the new year was an entertaining success. Dr. Anthony Twarog presented a talk on the recent discovery of a number of radio bursts which are exceptionally bright but occur only once for a few seconds and disappear. Non-repeatable events, as exemplified by the WOW signal from a radio survey in the 70s, are intriguing, but a challenge to understand. Current interpretations are focused on astrophysical exotica like instabilities in magnetars. We’ll keep you posted. Our normally scheduled March meeting would fall during Spring Break, so we will delay the next meeting until April. As so often happens this time of year, our plans to use the new location on west campus—the Marching Band Practice Field—for public observing were wrecked by the snow and clouds over the weekend. We will try again at the end of March, the 29th to be exact. As noted on pg. 5, some club members are attempting to turn the old KANU receiver into a radio telescope—if you think you can help in the effort, contact Bill Wachspress (bill@wachspress.net).

A STELLAR WELCOME TO NEW MEMBERS:
Zachary Boehm
Jasmyne Kemp

Of Local Interest

85 Years after Pluto’s Discovery, NASA’s New Horizons Spots Small Moons Orbiting Pluto

Exactly 85 years after Clyde Tombaugh’s historic discovery of Pluto, the NASA spacecraft set to encounter the icy dwarf planet this summer is providing its first views of the small moons orbiting Pluto.

The moons Nix and Hydra are visible in a series of images taken by the New Horizons spacecraft from Jan. 27-Feb. 8, at distances ranging from about 125 million to 115 million miles (201 million to 186 million kilometers). The long-exposure images offer New Horizons’ best view yet of these two small moons circling Pluto which Tombaugh discovered at Lowell Observatory in Flagstaff, Arizona, on Feb. 18, 1930.

“Professor Tombaugh’s discovery of Pluto was far ahead its time, heralding the discovery of the Kuiper Belt and a new class of planet,” says Alan Stern, New Horizons principal investigator from Southwest Research Institute, Boulder, Colorado. “The New Horizons team salutes his historic accomplishment.”

(Continued on page 2)
These are the first of a series of long-exposure images that will continue through early March, with the purpose of refining the team’s knowledge of the moons’ orbits. Each frame is a combination of five 10-second images, taken with New Horizons’ Long-Range Reconnaissance Imager (LORRI) using a special mode that combines pixels to increase sensitivity at the expense of resolution. At left, Nix and Hydra are just visible against the glare of Pluto and its large moon Charon, and the dense field of background stars. The bright and dark streak extending to the right of Pluto is an artifact of the camera electronics, resulting from the overexposure of Pluto and Charon. As can be seen in the movie, the spacecraft and camera were rotated in some of the images to change the direction of this streak, in order to prevent it from obscuring the two moons.

The right-hand images have been processed to remove most of Pluto and Charon’s glare, and most of the background stars. The processing leaves blotchy and streaky artifacts in the images, and also leaves a few other residual bright spots that are not real features, but makes Nix and Hydra much easier to see. Celestial north is inclined 28 degrees clockwise from the “up” direction in these images.

Nix and Hydra were discovered by New Horizons team members in Hubble Space Telescope images taken in 2005. Hydra, Pluto’s outermost known moon, orbits Pluto every 38 days at a distance of approximately 40,200 miles (64,700 km), while Nix orbits every 25 days at a distance of 30,260 miles (48,700 km). Each moon is probably between 25-95 miles (approximately 40-150 kilometers) in diameter, but scientists won’t know their sizes more precisely until New Horizons obtains close-up pictures of both of them in July. Pluto’s two other small moons, Styx and Kerberos, are still smaller and too faint to be seen by New Horizons at its current range to Pluto; they will become visible in the months to come.

“It’s thrilling to watch the details of the Pluto system emerge as we close the distance to the spacecraft’s July 14 encounter,” says New Horizons science team member John Spencer, also from Southwest Research Institute. “This first good view of Nix and Hydra marks another major milestone, and a perfect way to celebrate the anniversary of Pluto’s discovery.”

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
A Review of the book

The Universe by Tom Jackson
Shelter Harbor Press, New York, 2012

Another beautiful large coffee table book in Brit Tom Jackson’s "Illustrated History of the Foundations of Science" series is, “An Illustrated History of Astronomy.” Like Physics, reviewed in the October Celestial Mechanic, the author selects the 100 topics most descriptive of the breakthroughs leading to our current understanding of, in this case, the Universe. Its 143 pages are based on Jackson’s concept of the weightiest problems that became (chronological) discoveries and changed the way we understand the astronomical universe. His introduction begins with the patterns the ancients saw in the starry sky and the exceptions—planets, novae, comets, eclipses, etc. that slowly offered clues to the questions, “Where am I and where did I come from?” Two pages then graphically illustrate the diverse scales of the known universe.

The author believes that great discoveries make great stories, and each of the one- or two-page descriptions of the 100 history topics is very much told and illustrated as a story. The stories are based on people, concepts, instruments, and adventures of discovery. That approach enables Jackson to go surprisingly deep while variety holds one’s interest; his use of classical art and historic manuscript selections and photos, is excellent. There is cleverness, too (see his bio of astronomer Fritz Zwicky).

A glance at the Contents will remind the amateur how we historically learned of the scale of the universe. CENTER OF THE UNIVERSE has 13 sections from Star Monuments to Ptolemy’s “Almagest.” FINDING EARTH’S PLACE has 20 sections from the Astrolabe to the Age of the Earth. Next, 14 sections, GREATER, FARTHER, LONGER, run from a New Planet to Standardizing Time. This and the final two sections chronologically introduce our understanding of astrophysics and explain engineering topics. REACHING FOR THE STARS has 25 sections extending from Space Travel to Project Apollo, with more astrophysics. Finally, THE NEXT FRONTIER has 25 sections covering Space Stations to A New Earth. The new earths are the planets discovered around other stars. Amazingly, there may be more planets than stars in the universe!

Appendix material helps to increase the effective depth of The Universe. There are Illustrated biographical sketches of 39 astronomers, six of whom are also in Physics. Eight pages are graphics-rich Astronomy 101 with basic physics included. The “Imponderables” speculations include Aliens, Theory of Everything, and Before the Big Bang? The 15-column index is welcome.

A pocket in the back of this book contains something unique—a two-sided folding table, 82 INCHES LONG when unfolded. The front is a four-tier timeline placing major astronomical events and discoveries against inventions, world events, and culture. For example, around 3200 BCE the first constellations of the zodiac were noted, writing developed, Egypt was unified, and the Jewish calendar begins. About 2011, the Messenger probe orbits Mercury, 2 billion people use the Internet, a Japanese nuclear plant is destroyed, and Dubai opens the world’s tallest building. The back of the table has 12 monthly star charts for Northern and Southern Hemispheres.

There are many well-illustrated popular and text-book astronomy volumes at various levels. And there is the history, invention, and culture linking approach too, especially the updated Cosmos book by Sagan and the two Cosmos DVDs, 1980 (updated) and 2014, some 13 half-hours each. So what is the role of the gorgeous volume The Universe? It does not cover some human concerns about the cosmos such as planet warming and extinctions. Some complex subjects like space-time and parallax can only be introduced in passing.

But, an attractive coffee-table book organized as this one is, is more easily referenced, portable, and accessible on a daily basis than DVDs of equal authority and requires less commitment than the Cosmos book and DVDs. This book may introduce many more to the subject initially, and prepare them for Cosmos products. Its price is comparable (thanks, China). The book is highly recommended to amateur astronomers and others and would be a great initial reference for public libraries.
The heavyweight champion of the Cosmos

By Dr. Ethan Siegel

As crazy as it once seemed, we once assumed that the Earth was the largest thing in all the universe. 2,500 years ago, the Greek philosopher Anaxagoras was ridiculed for suggesting that the Sun might be even larger than the Peloponnesus peninsula, about 16% of modern-day Greece. Today, we know that planets are dwarfed by stars, which themselves are bound together by the billions or even trillions into galaxies.

But gravitationally bound structures extend far beyond galaxies, which themselves can bind together into massive clusters across the cosmos. While dark energy may be driving most galaxy clusters apart from one another, preventing our local group from falling into the Virgo Cluster, for example, on occasion, huge galaxy clusters can merge, forming the largest gravitationally bound structures in the universe.

Take the “El Gordo” galaxy cluster, catalogued as ACT-CL J0102-4915. It’s the largest known galaxy cluster in the distant universe. A galaxy like the Milky Way might contain a few hundred billion stars and up to just over a trillion ($10^{12}$) solar masses worth of matter, the El Gordo cluster has an estimated mass of $3 \times 10^{15}$ solar masses, or 3,000 times as much as our own galaxy! The way we’ve figured this out is fascinating. By seeing how the shapes of background galaxies are distorted into more elliptical-than-average shapes along a particular set of axes, we can reconstruct how much mass is present in the cluster: a phenomenon known as weak gravitational lensing. That reconstruction is shown in blue, but doesn’t match up with where the X-rays are, which are shown in pink! This is because, when galaxy clusters collide, the neutral gas inside heats up to emit X-rays, but the individual galaxies (mostly) and dark matter (completely) pass through one another, resulting in a displacement of the cluster’s mass from its center. This has been observed before in objects like the Bullet Cluster, but El Gordo is much younger and farther away. At 10 billion light-years distant, the light reaching us now was emitted more than 7 billion years ago, when the universe was less than half its present age.

It’s a good thing, too, because about 6 billion years ago, the universe began accelerating, meaning that El Gordo just might be the largest cosmic heavyweight of all. There’s still more universe left to explore, but for right now, this is the heavyweight champion of the distant universe!

AAL MEMBERS AT WORK!

Two images of volunteers dismantling the obsolete KANU NPR dish. The plan is to turn it into a radio telescope and move it to the new Baker Wetlands Observatory. AAL member Rob Burk worked hard on this. That's his trailer with the dish on it. AAL member Reid Nelson labeled the parts to help us get it back together. Now I'm looking for people with radio engineering experience interested in helping plan the setup, and anyone to help motorize it. I don't expect to be expanding the boundaries of science with this. I just think it's a great opportunity to learn how radio astronomy works (and doesn't work) first hand.

Bill Wachspress

THE NEBRASKA STAR PARTY

July 12th THROUGH July 17, 2015
SNAKE CAMPGROUND, MERRITT RESERVOIR, 27 MILES SOUTH OF VALENTINE, NEBRASKA

Plan now to sail off on your own voyage of discovery this summer with us! The astronomical views from Merritt Reservoir’s Snake Campground are fabulous, and there are plenty of recreational opportunities to keep the entire family entertained all week long at the 22nd annual Nebraska Star Party.

For newcomers, NSP is the perfect place to become acquainted with the wonders of the heavens which can’t be seen from cities. Our unique Beginner’s Field School will show you how fun it is to explore the sky here, as well as in your own back yard when you return home, with or without a telescope.

Whether you’ve been to NSP many times before, or you don’t even know what a star party is, you’ll be treated like a cherished old friend. Plan now to join us this summer for an unforgettable – and economical – vacation! You don’t even need a telescope to attend. Be sure to register before July 1st, 2015 to save $10 per adult on registration costs. For more info, go to http://www.nebraskastarparty.org/

Are you new to astronomy? Don’t have a telescope? If you’ve never attended a star party before, or if you’ve been to other star parties but need more information about what to expect at NSP, check out our Frequently Asked Questions page.
Living on the Edge: Stars Found Far from Galaxy Center

Brazilian astronomers have made a remarkable discovery: a cluster of stars forming on the very edge of the Galaxy. The team, led by Denilso Camargo of the Federal University of Rio Grande do Sul in Porto Alegre, Brazil, publish their results in the journal *Monthly Notices of the Royal Astronomical Society*.

The Milky Way, the Galaxy we live in, has a barred spiral shape, with arms of stars, gas and dust winding out from a central bar. Viewed from the side, the Galaxy would appear relatively flat, with most of the material in a disc and the central regions. Stars form inside massive and dense clumps of gas in so-called giant molecular clouds (GMCs) that are mainly located in the inner part of the galactic disc. With many clumps in a single GMC, most (if not all) stars are born together in clusters.

Denilso’s team looked at data from NASA’s orbiting Wide-Field Infrared Survey Explorer (WISE) observatory. They not only found GMCs thousands of light years above and below the galactic disc, but that one of them unexpectedly contained two clusters of stars. This is the first time astronomers have found stars being born in such a remote location.

The other idea is that the interaction between our Galaxy and its satellites, the Magellanic Clouds, may have disturbed gas that falls into the Galaxy, again leading to the creation of GMCs and stars. Denilso commented: "Our work shows that the space around the Galaxy is a lot less empty than we thought. The new clusters of stars are truly exotic. In a few million years, any inhabitants of planets around the stars will have a grand view of the outside of the Milky Way, something no human being will probably ever experience."

"Now we want to understand how the ingredients for making stars made it to such a distant spot. We need more data and some serious work on computer models to try to answer this question."

The chimney model would need several hundred massive stars to have exploded as supernovae over several generations, creating a ‘superwind’ that threw HRK 81.4-77.8 into its present position. Over millions of years, the bubbles created by the explosions may then themselves compress material, forming more stars and fueling the ejection of material in a ‘galactic fountain’, where the dust and gas eventually rains back on to the disk.

(Continued from page 7)

G299 could be an example of such an “unusual” Type Ia supernova. Using a long observation from Chandra, researchers discovered the shell of debris from the exploded star is expanding differently in various directions. In this new Chandra image, red, green, and blue represent low, medium, and high-energy X-rays, respectively, detected by the telescope. The medium energy X-rays include emission from iron and the hard-energy X-rays include emission from silicon and sulfur. The X-ray data have been combined with infrared data from ground-based 2MASS survey that shows the stars in the field of view.

By performing a detailed analysis of the X-rays, researchers found several clear examples of asymmetry in G299. For example, the ratio between the amounts of iron and silicon in the part of the remnant just above the center is larger than in the part of the remnant just below the center. This difference can be seen in the greener color of the upper region compared to the bluer color of the lower region. Also, there is a strongly elongated portion of the remnant extending to the right. In this region, the relative amount of iron to silicon is similar to that found in the southern region of the remnant.

The patterns seen in the Chandra data suggest that a very lopsided explosion may have produced this Type Ia supernova. It might also be that the remnant has been expanding into an environment where the medium it encountered was uneven. Regardless of the ultimate explanation, observations of G299 and others like it are showing astronomers just how varied such beautiful cosmic flowers can be.
Exploded Star Blooms Like a Cosmic Flower

Because the debris fields of exploded stars, known as supernova remnants, are very hot, energetic, and glow brightly in X-ray light, NASA’s Chandra X-ray Observatory has proven to be a valuable tool in studying them. The supernova remnant called G299.2-2.9 (or G299 for short) is located within our Milky Way galaxy, but Chandra’s new image of it is reminiscent of a beautiful flower here on Earth.

G299 was left over by a particular class of supernovas called Type Ia. Astronomers think that a Type Ia supernova is a thermonuclear explosion – involving the fusion of elements and release of vast amounts of energy – of a white dwarf star in a tight orbit with a companion star. If the white dwarf’s partner is a typical, Sun-like star, the white dwarf can become unstable and explode as it draws material from its companion. Alternatively, the white dwarf is in orbit with another white dwarf, the two may merge and can trigger an explosion.

Regardless of their triggering mechanism, Type Ia supernovas have long been known to be uniform in their extreme brightness, usually outshining the entire galaxy where they are found. This is important because scientists use these objects as cosmic mileposts, allowing them to accurately measure the distances of galaxies billions of light years away, and to determine the rate of expansion of the Universe. Traditional theoretical models of Type Ia supernovas generally predict that these explosions would be symmetric, creating a near perfect sphere as they expand. These models have been supported by results showing that remnants of Type Ia supernovas are more symmetric than remnants of supernovas involving the collapse of massive stars.

However, astronomers are discovering that some Type Ia supernova explosions may not be as symmetric as previ-
Astronomers have used NASA’s Hubble Space Telescope to take the most detailed picture to date of a large, edge-on, gas-and-dust disk encircling the 20-million-year-old star Beta Pictoris.

Beta Pictoris remains the only directly imaged debris disk that has a giant planet (discovered in 2009). Because the orbital period is comparatively short (estimated to be between 18 and 22 years), astronomers can see large motion in just a few years. This allows scientists to study how the Beta Pictoris disk is distorted by the presence of a massive planet embedded within the disk. The new visible-light Hubble image traces the disk in closer to the star to within about 650 million miles of the star (which is inside the radius of Saturn’s orbit about the Sun).

“Some computer simulations predicted a complicated structure for the inner disk due to the gravitational pull by the short-period giant planet. The new images reveal the inner disk and confirm the predicted structures. This finding validates models, which will help us to deduce the presence of other exoplanets in other disks,” said Daniel Apai of the University of Arizona. The gas-giant planet in the Beta Pictoris system was directly imaged in infrared light by the European Southern Observatory’s Very Large Telescope six years ago.

When comparing the latest Hubble images to Hubble images taken in 1997, astronomers find that the disk’s dust distribution has barely changed over 15 years despite the fact that the entire structure is orbiting the star like a carousel. This means the disk’s structure is smoothly continuous in the direction of its rotation on the timescale, roughly, of the accompanying planet’s orbital period.

In 1984 Beta Pictoris was the very first star discovered to host a bright disk of light-scattering circumstellar dust and debris. Ever since then Beta Pictoris has been an object of intensive scrutiny with Hubble and with ground-based telescopes. Hubble spectroscopic observations in 1991 found evidence for extrasolar comets frequently falling into the star. The disk is easily seen because it is tilted edge-on and is especially bright due to a very large amount of starlight-scattering dust. What’s more, Beta Pictoris is closer to Earth (63 light-years) than most of the other known disk systems.

Though nearly all of the approximately two-dozen known light-scattering circumstellar disks have been viewed by Hubble to date, Beta Pictoris is the first and best example of what a young planetary system looks like, say researchers. One thing astronomers have recently learned about circumstellar debris disks is that their structure, and amount of dust, is incredibly diverse and may be related to the locations and masses of planets in those systems. “The Beta Pictoris disk is the prototype for circumstellar debris disks, but it may not be a good archetype,” said co-author Glenn Schneider of the University of Arizona.

For one thing the Beta Pictoris disk is exceptionally dusty. This may be due to recent major collisions among unseen planetary-sized and asteroid-sized bodies embedded within it. In particular, a bright lobe of dust and gas on the southwestern side of the disk may be the result of the pulverization of a Mars-sized body in a giant collision.

Both the 1997 and 2012 images were taken in visible light with Hubble’s Space Telescope Imaging Spectrograph in its coronagraphic imaging mode. A coronagraph blocks out the glare of the central star so that the disk can be seen.
NASA's Chandra Finds Intriguing Member of Black Hole Family Tree

A newly discovered cosmic object may help provide answers to some long-standing questions about how black holes evolve and influence their surroundings, according to a new study using NASA's Chandra X-ray Observatory.

"In paleontology, the discovery of certain fossils can help scientists fill in the evolutionary gaps between different dinosaurs," said Mar Mezcua of the Harvard-Smithsonian Center for Astrophysics, who led the study. "We do the same thing in astronomy, but we often have to 'dig' up our discoveries in galaxies that are millions of light years away."

The intriguing object, called NGC2276-3c, is located in an arm of the spiral galaxy NGC 2276, which is about 100 million light years from Earth. NGC2276-3c appears to be what astronomers call an "intermediate-mass black hole" (IMBH). For many years, scientists have found conclusive evidence for smaller black holes that contain about five to thirty times the mass of the sun. There is also a lot of information about so-called supermassive holes that reside at the center of galaxies and weigh millions or even billions times the sun's mass.

As their name suggests, IMBHs represent a class of black holes that fall in between these two well-established groups, with masses in the range of a few hundred to a few hundred thousand solar masses. One reason that IMBHs are important is that they could be the seeds from which supermassive black holes formed in the early universe.

"Astronomers have been looking very hard for these medium-sized black holes," said co-author Tim Roberts of the University of Durham in the UK. "There have been hints that they exist, but the IMBHs have been acting like a long-lost relative that isn’t interested in being found."

To learn about NGC2276-3c, the researchers observed it at almost the same time in X-rays with Chandra and in radio waves with the European Very Long Baseline Interferometry (VLBI) Network. The X-ray and radio data, along with an observed relation between radio and X-ray luminosities for sources powered by black holes, were used to estimate the black hole’s mass. A mass of about 50,000 times that of the sun was obtained, placing it in the range of IMBHs.

"We found that NGC2276-3c has traits similar to both stellar-mass black holes and supermassive black holes" said co-author Andrei Lobanov of the Max Planck Institute for Radio Astronomy in Bonn, Germany. "In other words, this object helps tie the whole black hole family together."

In addition to its mass, another remarkable property of NGC2276-3c is that it has produced a powerful radio jet that extends up to 2,000 light years. The region along the jet that extends for about 1,000 light years from NGC2276-3c seems to be missing young stars. This provides evidence that the IMBH may have had a strong influence on its environment, as the jet could have cleared out a cavity in the gas and suppressed the formation of new stars. Further studies of the NGC2276-3c jet could provide insight into the potentially large effects that supermassive black hole seeds in the early universe have had on their surroundings. The location of this IMBH in a spiral arm of NGC 2276 raises other questions. Was it formed within the galaxy, or did it come from the center of a dwarf galaxy that collided and merged with NGC 2276 in the past?

This IMBH is one of eight ultraluminous X-ray sources (ULXs) in NGC 2276 studied by Anna Wolter of the National (Continued on page 10)
Institute for Astrophysics (INAF) in Milan, Italy, and her colleagues. Hundreds of ULXs have been detected in the last 30 years; however, the nature of these sources is still a matter of debate, with some thought to contain IMBHs. Chandra observations show that one apparent ULX observed by ESA’s XMM-Newton is actually five separate ULXs, including NGC2276-3c. Wolter’s study concluded that about five to fifteen solar masses worth of stars are forming each year in NGC 2276. This high rate of star formation may have been triggered by a collision with a dwarf galaxy, supporting the merger idea for the IMBH’s origin. An interactive image, a podcast, and a video about these findings are available at: http://chandra.si.edu

Hubble Celebrates 24th Anniversary with Infrared Look at Nearby Star Factory
This colorful Hubble Space Telescope mosaic of a small portion of the Monkey Head Nebula unveils a collection of carved knots of gas and dust silhouetted against glowing gas. The cloud is sculpted by ultraviolet light eating into the cool hydrogen gas. As the interstellar dust particles are warmed from the radiation from the stars in the center of the nebula, they heat up and begin to glow at infrared wavelengths, as captured by Hubble. The space photo superficially resembles the "The Great Wave" print by 19th century Japanese artist Katsushika Hokusai.