Report from the Officers

The February meeting went off without a hitch and the skies cleared enough to allow some anxious but enthusiastic parents and kids to view the celestial sphere. The talk for the evening centered in the rapidly growing belief among astronomers that a ninth planet, about 10 times the size of Earth, probably sits hundreds of AUs away from the sun. While the existence of such an object had been speculated on for decades, the evidence to support it was meager to non-existent. Recent discovery of a growing sample of self-explanatory trans-Neptunian objects, especially deep into the Kuiper belt, and their orbital alignment has allowed astronomers to explain their coincidental orbits as a byproduct of the interaction with said planet. Unfortunately for all but a few well-placed astronomers, the distance to this planet is so large that unless one has ready access to a backyard 8-m telescope, the definitive identification of the object is probably a few years away when the Large Synoptic Survey Telescope becomes operational, unless the orbit is much more tightly constrained in the near future. Speaking of newly discovered planets, the big story for the month was the NASA announcement of a large sample of Earth-like planets in the habitable zone around the star Trappist—1 (see pg. 3). What’s intriguing is the fact that this star is typical of the most common class of normal stars, small mass and cool, found within our Galaxy.

(Continued on page 2)
The club is open to all people interested in sharing their love for astronomy. Beginning in Fall 2016, monthly meetings are scheduled as well. For more information, please contact the club officers: president, Rick Heschmeyer at rcjbm@sbcglobal.net; 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 Sundays when events are scheduled. The information about AAL can be found at [http://www.physics.ku.edu/AAL/](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](http://www.physics.ku.edu/AAL/newsletter).

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About the Astronomy Associates of Lawrence

The club is open to all people interested in sharing their love for astronomy. Beginning in Fall 2016, monthly meetings are typically on the last Sunday of each month and often feature guest speakers, presentations by club members, and a chance to exchange amateur astronomy tips. These meetings and the public observing sessions that follow are scheduled at the Baker Wetlands Discovery Center, south of Lawrence. All events and meetings are free and open to the public. Periodic star parties are also scheduled as well. For more information, please contact the club officers: president, Rick Heschmeyer at rcjbm@sbcglobal.net; 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 Sundays when events are scheduled. The information about AAL can be found at [http://www.physics.ku.edu/AAL/](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](http://www.physics.ku.edu/AAL/newsletter).
NASA Telescope Reveals Largest Batch of Earth-Size, Habitable-Zone Planets Around Single Star

NASA's Spitzer Space Telescope has revealed the first known system of seven Earth-size planets around a single star. Three of these planets are firmly located in the habitable zone, the area around the parent star where a rocky planet is most likely to have liquid water. The discovery sets a new record for greatest number of habitable-zone planets found around a single star outside our solar system. All of these seven planets could have liquid water — key to life as we know it — under the right atmospheric conditions, but the chances are highest with the three in the habitable zone. "This discovery could be a significant piece in the puzzle of finding habitable environments, places that are conducive to life," said Thomas Zurbuchen, associate administrator of the agency's Science Mission Directorate. "Answering the question 'are we alone' is a top science priority and finding so many planets like these for the first time in the habitable zone is a remarkable step forward toward that goal."

At about 40 light-years (235 trillion miles) from Earth, the system of planets is relatively close to us, in the constellation Aquarius. Because they are located outside of our solar system, these planets are scientifically known as exoplanets. This exoplanet system is called TRAPPIST-1, named for The Transiting Planets and Planetesimals Small Telescope (TRAPPIST) in Chile. In May 2016, researchers using TRAPPIST announced they had discovered three planets in the system. Assisted by several ground-based telescopes, including the European Southern Observatory's Very Large Telescope, Spitzer confirmed the existence of two of these planets and discovered five additional ones, increasing the number of known planets in the system to seven. Using Spitzer data, the team precisely measured the sizes of the seven planets and developed first estimates of the masses of six of them, allowing their density to be estimated. Based on their densities, all of the TRAPPIST-1 planets are likely to be rocky. Further observations will not only help determine whether they are rich in water, but also possibly reveal whether any could have liquid water on their surfaces. The mass of the seventh and farthest exoplanet has not yet been estimated — scientists believe it could be an icy, "snowball-like" world, but further observations are needed.

"The seven wonders of TRAPPIST-1 are the first Earth-size planets that have been found orbiting this kind of star," said Michael Gillon, lead author of the paper and the principal investigator of the TRAPPIST exoplanet survey at the University of Liege, Belgium. "It is also the best target yet for studying the atmospheres of potentially habitable, Earth-size worlds."

In contrast to our sun, the TRAPPIST-1 star — classified as an ultra-cool dwarf — is so cool that liquid water could survive on planets orbiting very close to it, closer than is possible on planets in our solar system. All seven of the TRAPPIST-1 planetary orbits are closer to their host star than Mercury is to our sun. The planets also are very close to each other. If a person was standing on one of the planet's surface, they could gaze up and potentially see geological features or clouds of neighboring worlds, which would sometimes appear larger than the moon in Earth's sky. The planets may also be tidally locked to their star, which means the same side of the planet is always facing the star, therefore each side is either perpetual day or night. This could mean they have weather patterns totally unlike those on Earth, such as strong winds blowing from the day side to the night side, and extreme temperature changes. Spitzer, an infrared telescope that trails Earth as it orbits the sun, was well-suited for studying TRAPPIST-1 because the star glows brightest in infrared light, whose wavelengths are longer than the eye can see. In the fall of 2016, Spitzer observed TRAPPIST-1 nearly continuously for 500 hours. Spitzer is uniquely positioned in its orbit to observe enough crossing — transits — of the planets in front of the host star to reveal the complex architecture of the system. Engineers optimized Spitzer's ability to observe transiting planets during Spitzer's "warm mission," which began after the spacecraft's coolant ran out as planned after the first five years of operations.

"This is the most exciting result I have seen in the 14 years of Spitzer operations," said Sean Carey, manager of NASA's Spitzer Science Center at Caltech/IPAC in Pasadena, California. "Spitzer will follow up in the fall to further refine our understanding of these planets so that the James Webb Space Telescope can follow up. More observations of the system are sure to reveal more secrets."

Following up on the Spitzer discovery, NASA's Hubble Space Telescope has initiated the screening of four of the planets.

(Continued on page 2)
Solar Eclipse Provides Coronal Glimpse

By Marcus Woo

On August 21, 2017, North Americans will enjoy a rare treat: The first total solar eclipse visible from the continent since 1979. The sky will darken and the temperature will drop, in one of the most dramatic cosmic events on Earth. It could be a once-in-a-lifetime show indeed. But it will also be an opportunity to do some science.

Only during an eclipse, when the moon blocks the light from the sun's surface, does the sun’s corona fully reveal itself. The corona is the hot and wispy atmosphere of the sun, extending far beyond the solar disk. But it's relatively dim, merely as bright as the full moon at night. The glaring sun, about a million times brighter, renders the corona invisible.

"The beauty of eclipse observations is that they are, at present, the only opportunity where one can observe the corona [in visible light] starting from the solar surface out to several solar radii," says Shadia Habbal, an astronomer at the University of Hawaii. To study the corona, she’s traveled the world having experienced 14 total eclipses (she missed only five due to weather). This summer, she and her team will set up identical imaging systems and spectrometers at five locations along the path of totality, collecting data that's normally impossible to get.

Ground-based coronographs, instruments designed to study the corona by blocking the sun, can't view the full extent of the corona. Solar space-based telescopes don't have the spectrographs needed to measure how the temperatures vary throughout the corona. These temperature variations show how the sun’s chemical composition is distributed—crucial information for solving one of long-standing mysteries about the corona: how it gets so hot. While the sun's surface is ~9980 Farenheit (~5800 Kelvin), the corona can reach several millions of degrees Farenheit. Researchers have proposed many explanations involving magneto-acoustic waves and the dissipation of magnetic fields, but none can account for the wide-ranging temperature distribution in the corona, Habbal says.

You too can contribute to science through one of several citizen science projects. For example, you can also help study the corona through the Citizen CATE experiment; help produce a high definition, time-expanded video of the eclipse; use your ham radio to probe how an eclipse affects the propagation of radio waves in the ionosphere; or even observe how wildlife responds to such a unique event. Otherwise, Habbal still encourages everyone to experience the eclipse. Never look directly at the sun, of course (find more safety guidelines here: https://eclipse2017.nasa.gov/safety). But during the approximately 2.5 minutes of totality, you may remove your safety glasses and watch the eclipse directly—only then can you see the glorious corona. So enjoy the show. The next one visible from North America won't be until 2024.

For more information about the upcoming eclipse, please see: NASA Eclipse citizen science page https://eclipse2017.nasa.gov/citizen-science.

Illustration showing the United States during the total solar eclipse of August 21, 2017, with the umbra (black oval), penumbra (concentric shaded ovals), and path of totality (red) through or very near several major cities. Credit: Goddard Science Visualization Studio, NASA
A Supernova at 150 Light Years: What Happened to the Earth?

Prof. Adrian Melott  
Department of Physics & Astronomy  
University of Kansas

Prof. Melott will discuss recent results that have strongly confirmed that multiple supernovae happened at distances ~150 light years consisting of two main events: one at 1.7 to 3.2 million years ago, and the other at 6.5 to 8.7 million years ago. These events are said to be responsible for excavating the Local Bubble in the interstellar medium and depositing iron-60 on Earth and the Moon. Other events are indicated by effects in the local cosmic ray spectrum. Given this updated and refined picture, we ask whether such supernovae are expected to have had substantial effects on the terrestrial atmosphere and biota. In a first cut at the most probable cases, combining photon and cosmic ray effects, we find that a supernova at 150 light years can have only a small effect on terrestrial organisms from visible light and that chemical changes such as ozone depletion are weak. However, tropospheric ionization right down to the ground due to the penetration of $\geq$TeV cosmic rays will increase by nearly an order of magnitude for thousands of years and irradiation by muons on the ground and in the upper ocean will increase 20-fold, which will approximately triple the overall radiation load on terrestrial organisms. Such irradiation has been linked to possible changes in climate, increased wildfires, and increased cancer and mutation rates. This may be related to a minor mass extinction around the Pliocene-Pleistocene boundary and further research on the effects is needed.

Thursday  
March 9, 2017  
7:00 p.m.  
Lawrence Public Library Auditorium  
707 Vermont St.  
Lawrence, KS 66044

About Professor Adrian Melott:  
Adrian Melott is currently Professor of Physics and Astronomy at the University of Kansas. He received his Ph.D. at the University of Texas in 1981. He was one of the pioneers in simulation of the formation of structure in a dark-matter dominated Universe. In 1996 he was named a Fellow of the American Physical Society “for groundbreaking studies of the origin and evolution of cosmic structure”, and in 2002 received the APS Joseph A. Burton Forum Award “to recognize outstanding contributions to public understanding or resolution of issues involving the interface of physics and society.” He was organizer and founder of Kansas Citizens for Science, which played a major role in restoring evolutionary biology to public science standards. Recently he shifted his research to “astrobiophysics”, beginning with the possible role of gamma-ray bursts in terrestrial mass extinctions, as well as long-term biodiversity fluctuations. In 2007 he was named Fellow of the American Association for the Advancement of Science “for distinguished contributions to cosmological large-scale structure, for organizing public support for teaching evolution, and for interdisciplinary research on astrophysical impacts on the biosphere.”

Public Lecture  
For more information:  
785-864-4626  
physics@ku.edu  
http://physics.ku.edu
Hubble’s Legacy: Reflections on the Past, Present, & Future of U.S. Astronomy

Prof. Daniel H. McIntosh
University of Missouri—Kansas City

Friday
April 14, 2017
7:00 p.m.

Kansas Room
Kansas Union
1301 Jayhawk Blvd.
Lawrence, KS 66045

In April 1990, NASA launched the most well-known scientific instrument in history. As an astronomer, educator and U.S. citizen I have reflected on more than 25 years of the Hubble Space Telescope. I will describe the legacies of this great space observatory, illuminate who Edwin Hubble was and why this telescope was named after him, and explain how astronomical science was different in his time compared to today. I will finish by examining the questions "how much did it cost to build the space observatory and was it worth it?". The answers to these questions relate to the future of science in the U.S.

About Professor Daniel H. McIntosh:
Dr. McIntosh is a Distinguished Associate Professor of Astronomy and Astrophysics. Since joining the University of Missouri-Kansas City in August 2008, Prof. McIntosh has established a vibrant astronomy program, founded the UMKC Galaxy Evolution Group, and developed many educational innovations dedicated to actively engaging students from all backgrounds in positive and impactful learning experiences related to science. In 2016, he was awarded the UMKC System President’s Award for Innovative Teaching. Dr. McIntosh is also an expert on the physical processes underlying the origins and growth of galaxies - a central feature of cosmic history. Much of his research over the last 16 years has employed data collected by the Hubble Space Telescope.

Public Event

For more information:
785-864-4626
physics@ku.edu
http://physics.ku.edu
NASA’s Fermi Finds Possible Dark Matter Ties in Andromeda Galaxy

NASA’s Fermi Gamma-ray Space Telescope has found a signal at the center of the neighboring Andromeda galaxy that could indicate the presence of the mysterious stuff known as dark matter. The gamma-ray signal is similar to one seen by Fermi at the center of our own Milky Way galaxy. Gamma rays are the highest-energy form of light, produced by the universe’s most energetic phenomena. They’re common in galaxies like the Milky Way because cosmic rays, particles moving near the speed of light, produce gamma rays when they interact with interstellar gas clouds and starlight. Surprisingly, the latest Fermi data shows the gamma rays in Andromeda — also known as M31 — are confined to the galaxy’s center instead of spread throughout. To explain this unusual distribution, scientists are proposing that the emission may come from several undetermined sources. One of them could be dark matter, an unknown substance that makes up most of the universe.

“We expect dark matter to accumulate in the innermost regions of the Milky Way and other galaxies, which is why finding such a compact signal is very exciting,” said lead scientist Pierrick Martin, an astrophysicist at the National Center for Scientific Research and the Research Institute in Astrophysics and Planetology in Toulouse, France. “M31 will be a key to understanding what this means for both Andromeda and the Milky Way.”

Another possible source for this emission could be a rich concentration of pulsars in M31’s center. These spinning neutron stars weigh as much as twice the mass of the sun and are among the densest objects in the universe. One teaspoon of neutron star matter would weigh a billion tons on Earth. Some pulsars emit most of their energy in gamma rays. Because M31 is 2.5 million light-years away, it’s difficult to find individual pulsars. To test whether the gamma rays are coming from these objects, scientists can apply what they know about pulsars from observations in the Milky Way to new X-ray and radio observations of Andromeda. Now that Fermi has detected a similar gamma-ray signature in both M31 and the Milky Way, scientists can use this information to solve mysteries within both galaxies. For example, M31 emits few gamma rays from its large disk, where most stars form, indicating fewer cosmic rays roaming there. Because cosmic rays are usually thought to be related to star formation, the absence of gamma rays in the outer parts of M31 suggests either that the galaxy produces cosmic rays differently, or that they can escape the galaxy more rapidly. Studying Andromeda may help scientists understand the life cycle of cosmic rays and how it is connected to star formation.

“We don’t fully understand the roles cosmic rays play in galaxies, or how they travel through them,” said Xian Hou, an astrophysicist at Yunnan Observatories, Chinese Academy of Sciences in Kunming, China, also a lead scientist in this work. “M31 lets us see how cosmic rays behave under conditions different from those in our own galaxy.”

The similar discovery in both the Milky Way and M31 means scientists can use the galaxies as models for each other when making difficult observations. While Fermi can make more sensitive and detailed observations of the Milky Way’s center, its view is partially obscured by emission from the galaxy’s disk. But telescopes view Andromeda from an outside vantage point impossible to attain in the Milky Way. “Our galaxy is so similar to Andromeda, it really helps us to be able to study it, because we can learn more about our galaxy and its formation,” said co-author Regina Caputo, a research scientist at NASA’s Goddard Space Flight Center in Greenbelt, Maryland. “It’s like living in a world where there’s no mirrors but you have a twin, and you can see everything physical about the twin.”

While more observations are necessary to determine the source of the gamma-ray excess, the discovery provides an exciting starting point to learn more about both galaxies, and perhaps about the still elusive nature of dark matter. “We still have a lot to learn about the gamma-ray sky,” Caputo said. “The more information we have, the more information we can put into models of our own galaxy.”
The Dawn of a New Era for Supernova 1987A

Three decades ago, astronomers spotted one of the brightest exploding stars in more than 400 years. The titanic supernova, called Supernova 1987A (SN 1987A), blazed with the power of 100 million suns for several months following its discovery on Feb. 23, 1987. Since that first sighting, SN 1987A has continued to fascinate astronomers with its spectacular light show. Located in the nearby Large Magellanic Cloud, it is the nearest supernova explosion observed in hundreds of years and the best opportunity yet for astronomers to study the phases before, during, and after the death of a star.

To commemorate the 30th anniversary of SN 1987A, new images, time-lapse movies, a data-based animation based on work led by Salvatore Orlando at INAF-Osservatorio Astronomico di Palermo, Italy, and a three-dimensional model are being released. By combining data from NASA's Hubble Space Telescope and Chandra X-ray Observatory, as well as the international Atacama Large Millimeter/submillimeter Array (ALMA), astronomers — and the public — can explore SN 1987A like never before.

Hubble has repeatedly observed SN 1987A since 1990, accumulating hundreds of images, and Chandra began observing SN 1987A shortly after its deployment in 1999. ALMA, a powerful array of 66 antennas, has been gathering high-resolution millimeter and submillimeter data on SN 1987A since its inception.

"The 30 years' worth of observations of SN 1987A are important because they provide insight into the last stages of stellar evolution," said Robert Kirshner of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Massachusetts, and the Gordon and Betty Moore Foundation in Palo Alto, California.

The latest data from these powerful telescopes indicate that SN 1987A has passed an important threshold. The supernova shock wave is moving beyond the dense ring of gas produced late in the life of the pre-supernova star when a fast outflow or wind from the star collided with a slower wind generated in an earlier red giant phase of the star's evolution. What lies beyond the ring is poorly known at present, and depends on the details of the evolution of the star when it was a red giant.

"The details of this transition will give astronomers a better understanding of the life of the doomed star, and how it ended," said Kari Frank of Penn State University who led the latest Chandra study of SN 1987A.

Supernovas such as SN 1987A can stir up the surrounding gas and trigger the formation of new stars and planets. The gas from which these stars and planets form will be enriched with elements such as carbon, nitrogen, oxygen, and iron, which are the basic components of all known life. These elements are forged inside the pre-supernova star and during the supernova explosion itself, and then dispersed into their host galaxy by expanding supernova remnants. Continued studies of SN 1987A should give unique insight into the early stages of this dispersal. Some highlights from studies involving these telescopes include:

Hubble studies have revealed that the dense ring of gas around the supernova is glowing in optical light, and has a diameter of about a light-year. The ring was there at least 20,000 years before the star exploded. A flash of ultraviolet light from the explosion energized the gas in the ring, making it glow for decades.

(Continued on page 11)
A giant black hole ripped apart a star and then gorged on its remains for about a decade, according to astronomers. This is more than ten times longer than any observed episode of a star's death by black hole. Researchers made this discovery using data from NASA's Chandra X-ray Observatory and Swift satellite as well as ESA's XMM-Newton. The trio of orbiting X-ray telescopes found evidence for a "tidal disruption event" (TDE), wherein the tidal forces due to the intense gravity from a black hole can destroy an object — such as a star — that wanders too close. During a TDE, some of the stellar debris is flung outward at high speeds, while the rest falls toward the black hole. As it travels inwards to be ingested by the black hole, the material heats up to millions of degrees and generates a distinct X-ray flare.

"We have witnessed a star's spectacular and prolonged demise," said Dacheng Lin from the University of New Hampshire in Durham, New Hampshire, who led the study. "Dozens of tidal disruption events have been detected since the 1990s, but none that remained bright for nearly as long as this one."

The extraordinary long bright phase of this event spanning over ten years means that among observed TDEs this was either the most massive star ever to be completely torn apart during one of these events, or the first where a smaller star was completely torn apart. The X-ray source containing this force-fed black hole, known by its abbreviated name of XJ1500+0154, is located in a small galaxy about 1.8 billion light years from Earth.

The source was not detected in a Chandra observation on April 2nd, 2005, but was detected in an XMM-Newton observation on July 23rd, 2005, and reached peak brightness in a Chandra observation on June 5, 2008. These observations show that the source became at least 100 times brighter in X-rays. Since then, Chandra, Swift, and XMM-Newton have observed it multiple times. The sharp X-ray vision of Chandra data shows that XJ1500+0154 is located at the center of its host galaxy, the expected location for a supermassive black hole. The X-ray data also indicate that radiation from material surrounding this black hole has consistently surpassed the so-called Eddington limit, defined by a balance between the outward pressure of radiation from the hot gas and the inward pull of the gravity of the black hole.

"For most of the time we've been looking at this object, it has been growing rapidly," said co-author James Guillocron of the Harvard-Smithsonian Center for Astrophysics in Cambridge, Mass. "This tells us something unusual — like a star twice as heavy as our Sun — is being fed into the black hole."

The conclusion that supermassive black holes can grow, from TDEs and perhaps other means, at rates above those corresponding to the Eddington limit has important implications. Such rapid growth may help explain how supermassive black holes were able to reach masses about a billion times higher than the sun when the universe was only about a billion years old.

"This event shows that black holes really can grow at extraordinarily high rates," said co-author Stefanie Komossa of QianNan Normal University for Nationalities in Duyun City, China. "This may help understand how precocious black holes came to be."

Based on the modeling by the researchers the black hole's feeding supply should be significantly reduced in the next decade. This would result in XJ1500+0154 fading in X-ray brightness over the next several years.
Black-Hole-Powered Jets Forge Fuel for Star Formation

Astronomers using the Atacama Large Millimeter/submillimeter Array (ALMA) have discovered a surprising connection between a supermassive black hole and the galaxy where it resides. Powerful radio jets from the black hole – which normally suppress star formation – are stimulating the production of cold gas in the galaxy’s extended halo of hot gas. This newly identified supply of cold, dense gas could eventually fuel future star birth as well as feed the black hole itself.

The researchers used ALMA to study a galaxy at the heart of the Phoenix Cluster, an uncommonly crowded collection of galaxies about 5.7 billion light-years from Earth. The central galaxy in this cluster harbors a supermassive black hole that is in the process of devouring star-forming gas, which fuels a pair of powerful jets that erupt from the black hole in opposite directions into intergalactic space. Astronomers refer to this type of black-hole powered system as an active galactic nucleus (AGN).

Earlier research with NASA’s Chandra X-ray observatory revealed that the jets from this AGN are carving out a pair of giant “radio bubbles,” huge cavities in the hot, diffuse plasma that surrounds the galaxy. These expanding bubbles should create conditions that are too inhospitable for the surrounding hot gas to cool and condense, which are essential steps for future star formation. The latest ALMA observations, however, reveal long filaments of cold molecular gas condensing around the outer edges of the radio bubbles. These filaments extend up to 82,000 light-years from either side of the AGN. They collectively contain enough material to make about 10 billion suns.

"With ALMA we can see that there’s a direct link between these radio bubbles inflated by the supermassive black hole and the future fuel for galaxy growth," said Helen Russell, an astronomer with the University of Cambridge, UK, and lead author on a paper appearing in the Astrophysical Journal. "This gives us new insights into how a black hole can regulate future star birth and how a galaxy can acquire additional material to fuel an active black hole." The new ALMA observations reveal previously unknown connections between an AGN and the abundance of cold molecular gas that fuels star birth.

"To produce powerful jets, black holes must feed on the same material that the galaxy uses to make new stars," said Michael McDonald, an astrophysicist at the Massachusetts Institute of Technology in Cambridge and coauthor on the paper. "This material powers the jets that disrupt the region and quenches star formation. This illustrates how black holes can slow the growth of their host galaxies."

Without a significant source of heat, the most massive galaxies in the universe would be forming stars at extreme rates that far exceed observations. Astronomers believe that the heat, in the form of radiation and jets from an actively feeding supermassive black hole, prevents overcooling of the cluster's hot gas atmosphere, suppressing star formation. This story, however, now appears more complex. In the Phoenix Cluster, Russell and her team found an additional process that ties the galaxy and its black hole together. The radio jets that heat the core of the cluster's hot atmosphere also appear to stimulate the production of the cold gas required to sustain the AGN.

"That's what makes this result so surprising," said Brian McNamara, an astronomer at the University of Waterloo, Ontario, and co-author on the paper. "This supermassive black hole is regulating the growth of the galaxy by blowing bubbles and heating the gases around it. Remarkably, it also is cooling enough gas to feed itself."

This result helps astronomers understand the workings of the cosmic "thermostat" that controls the launching of radio jets from the supermassive black hole. "This could also explain how the most massive black holes were able to both suppress run-away starbursts and regulate the growth of their host galaxies over the past six billion years or so of cosmic history," noted Russell.
Nitrogen is a very important element for life as we know it,” Xu explained. “This particular object is quite rich in nitrogen, more so than any object observed in our solar system.

Our own Kuiper Belt, which extends outward from Neptune's orbit, is home to many dwarf planets, comets, and other small bodies left over from the formation of the solar system. Comets from the Kuiper Belt may have been responsible for delivering water and the basic building blocks of life to Earth billions of years ago. The new findings are observational evidence supporting the idea that icy bodies are also present in other planetary systems, and have survived throughout the history of the star's evolution.

To study the white dwarf's atmosphere, the team used both Hubble and the W. M. Keck Observatory. The measurements of nitrogen, carbon, oxygen, silicon, sulfur, iron, nickel, and hydrogen all come from Hubble, while Keck provides the calcium, magnesium, and hydrogen. The ultraviolet vision of Hubble's Cosmic Origins Spectrograph (COS) allowed the team to make measurements that are very difficult to do from the ground.

This is the first object found outside our solar system that is akin to Halley's Comet in composition. The team used the famous comet for comparison because it has been so well studied. The white dwarf is roughly 170 light-years from Earth in the constellation Boötes, the Herdsman. It was first recorded in 1974 and is part of a wide binary system, with a companion star separated by 2,000 times the distance that the Earth is from the sun.
Hubble Witnesses Massive Comet-Like Object Pollute Atmosphere of a White Dwarf

Scientists using NASA’s Hubble Space Telescope have witnessed a massive object with the makeup of a comet being ripped apart and scattered in the atmosphere of a white dwarf, the burned-out remains of a compact star. The object has a chemical composition similar to Halley’s Comet, but it is 100,000 times more massive and has a much higher amount of water. It is also rich in the elements essential for life, including nitrogen, carbon, oxygen, and sulfur.

These findings are the best evidence yet for a belt of comet-like bodies orbiting the white dwarf, similar to our solar system’s Kuiper Belt. These icy bodies apparently survived the star’s evolution as it became a bloated red giant and then collapsed to a small, dense white dwarf.

This artist’s concept shows a massive, comet-like object falling toward a white dwarf. New Hubble Space Telescope findings are evidence for a belt of comet-like bodies orbiting the white dwarf, similar to our solar system’s Kuiper Belt. The findings also suggest the presence of one or more unseen surviving planets around the white dwarf, which may have perturbed the belt to hurl icy objects into the burned-out star.

As many as 25 to 50 percent of white dwarfs are known to be polluted with infalling debris from rocky, asteroid-like objects, but this is the first time a body made of icy, comet-like material has been seen polluting a white dwarf’s atmosphere. The results also suggest the presence of unseen, surviving planets which may have perturbed the belt and worked as a “bucket brigade” to draw the icy objects into the white dwarf. The burned-out star also has a companion star which may disturb the belt, causing objects from the belt to travel toward the burned-out star.

Siyi Xu of the European Southern Observatory in Garching, Germany led the team that made the discovery. According to Xu, this was the first time that nitrogen was detected in the planetary debris that falls onto a white dwarf.

(Continued on page 11)