COMING EVENTS
Band Concert
Public Observing
Downtown Lawrence
South Park
west of Mass St.
Schedule
to be determined
9:30 PM

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Report from the Officers
We ended the Spring semester meetings with a big bang, in every way possible. About 75 people showed up to hear Prof. Feldman explain the fundamental observations of Cosmology that lead to the conclusion that the Universe began about 13.8 billion years ago with the mass-energy concentrated into an almost infinitesimally small region of spacetime. Equally important, the recent BICEP observations of polarization in the cosmic microwave background radiation, if confirmed, supply direct observational evidence of an event known as inflation, when the universe expanded by a factor of $10^{44}$ on a timescale of $10^{-33}$ sec. The gravitational waves created during this extraordinary expansion created a signature in the background radiation which has been seen for the first time.

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Dr. Hume Feldman, Chair of Physics & Astronomy and an internationally renowned cosmologist, (left) had no trouble filling the 75 minute presentation with amazing facts and insight which the audience clearly appreciated. If you missed it, you missed an exciting event.

Finally! Our last public observing session for the Spring semester at Prairie Park Nature Center went off without a hitch. The skies were dark and the temperatures comfortable. Club members were joined by the KU SEDS (Space Exploration and Development Society) club, who brought along their newly acquired telescope for checkout and testing. Though not as populated as the talk on Friday, everyone had a good time learning a little about observing the sky. We will try again in late May, picking up our usual schedule of observing downtown after the Wednesday Band Concerts as soon as the schedule for the concerts is officially posted.

ALCON 2014 Website is now "LIVE" The annual Astronomical League Convection this year is in San Antonio, Texas – July 10, 11, & 12, 2014. Log on to the site (http://alcon2014.astroleague.org/) and check the plans and registration in detail.

Perspectives on the Monuments of Mount Oread: A Stop Day Walking Tour of Kansas University

Conducted by Professor Emeritus Ted Johnson, Sponsored by the Department of Humanities and Western Civilization

The traditional marathon Stop Day walking tour of the campus consisting of informal, peripatetic, Socratic dialogues growing out of various sites will take place on Friday, May 9, 2014, from 9 a.m. to about 6 p.m. (bring friends and come and go as you please). The walking tour begins in front of the Natural History Museum, 14th Street and Jayhawk Boulevard, at 9 a.m.. For further information, please contact the Department of Humanities and Western Civilization at hwc@ku.edu or Professor Johnson at jtj@ku.edu.

Special Android Application now available from the NASA Space Place Program

For those of you familiar with our monthly SpacePlace column from NASA, Space Place Prime is now available on Android! A spinoff of NASA’s popular kids’ Space Place website (spaceplace.nasa.gov), Space Place Prime has timely, educational, and easy-to-read articles and activities from the Space Place and other science websites, the latest and most impressive NASA space and Earth imagery, and a wide array of informational movies. There is plenty to keep everyone occupied and informed. Content is updated daily, http://tinyurl.com/lyqme53.

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

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://groups.ku.edu/~astronomy

Copies of the Celestial Mechanic can also be found on the web at http://groups.ku.edu/~astronomy/celestialmechanic
Hubble Finds That Monster 'El Gordo' Galaxy Cluster Is Bigger Than Thought

NASA's Hubble Space Telescope has weighed the largest known galaxy cluster in the distant universe and found that it definitely lives up to its nickname: El Gordo (Spanish for "the fat one").

By precisely measuring how much the gravity from the cluster's mass warps images of far-more-distant background galaxies, a team of astronomers has calculated the cluster's mass to be as much as 3 million billion times the mass of our Sun. The Hubble data show that the cluster is roughly 43 percent more massive than earlier estimates based on X-ray and dynamical studies of the unusual cluster.

"It's given us an even stronger probability that this is really an amazing system very early in the universe," said team lead James Jee of the University of California at Davis.

A fraction of this mass is locked up in several hundred galaxies that inhabit the cluster and a larger fraction is in hot

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The Power of the Sun's Engines

By Dr. Ethan Siegel

Here on Earth, the sun provides us with the vast majority of our energy, striking the top of the atmosphere with up to 1,000 Watts of power per square meter, albeit highly dependent on the sunlight's angle-of-incidence. But remember that the sun is a whopping 150 million kilometers away, and sends an equal amount of radiation in all directions; the Earth-facing direction is nothing special. Even considering sunspots, solar flares, and long-and-short term variations in solar irradiance, the sun's energy output is always constant to about one-part-in-1,000. All told, our parent star consistently outputs an estimated $4 \times 10^{26}$ Watts of power; one second of the sun's emissions could power all the world's energy needs for over 700,000 years.

That's a literally astronomical amount of energy, and it comes about thanks to the hugeness of the sun. With a radius of 700,000 kilometers, it would take 109 Earths, lined up from end-to-end, just to go across the diameter of the sun once. Unlike our Earth, however, the sun is made up of around 70% hydrogen by mass, and it's the individual protons — or the nuclei of hydrogen atoms — that fuse together, eventually becoming helium-4 and releasing a tremendous amount of energy. All told, for every four protons that wind up becoming helium-4, a tiny bit of mass — just 0.7% of the original amount — gets converted into energy by $E=mc^2$, and that's where the sun's power originates.

You'd be correct in thinking that fusing $\sim 4 \times 10^{38}$ protons-per-second gives off a tremendous amount of energy, but remember that nuclear fusion occurs in a huge region of the sun: about the innermost quarter (in radius) is where 99% of it is actively taking place. So there might be $4 \times 10^{26}$ Watts of power put out, but that's spread out over $2.2 \times 10^{25}$ cubic meters, meaning the sun's energy output per-unit-volume is just 18 W / m$^3$. Compare this to the average human being, whose basal metabolic rate is equivalent to around 100 Watts, yet takes up just 0.06 cubic meters of space. In other words, you emit 100 times as much energy-per-unit-volume as the sun! It's only because the sun is so large and massive that its power is so great.

It's this slow process, releasing huge amounts of energy per reaction over an incredibly large volume, that has powered life on our world throughout its entire history. It may not appear so impressive if you look at just a tiny region, but — at least for our sun — that huge size really adds up!

Kids can learn more about an intriguing solar mystery at NASA's Space Place: [http://spaceplace.nasa.gov/sun-corona](http://spaceplace.nasa.gov/sun-corona).

Check out these “10 Need-to-Know Things About the Sun”: [http://solarsystem.nasa.gov/planets/profile.cfm?Object=Sun](http://solarsystem.nasa.gov/planets/profile.cfm?Object=Sun).
NASA’s Spitzer and WISE Telescopes Find Close, Cold Neighbor of Sun

NASA's Wide-field Infrared Survey Explorer (WISE) and Spitzer Space Telescope have discovered what appears to be the coldest "brown dwarf" known -- a dim, star-like body that surprisingly is as frosty as Earth's North Pole.

Images from the space telescopes also pinpointed the object's distance to 7.2 light-years away, earning it the title for fourth closest system to our sun. The closest system, a trio of stars, is Alpha Centauri, at about 4 light-years away.

"It's very exciting to discover a new neighbor of our solar system that is so close," said Kevin Luhman, an astronomer at Pennsylvania State University's Center for Exoplanets and Habitable Worlds, University Park. "And given its extreme temperature, it should tell us a lot about the atmospheres of planets, which often have similarly cold temperatures."

Brown dwarfs start their lives like stars, as collapsing balls of gas, but they lack the mass to burn nuclear fuel and radiate starlight. The newly discovered coldest brown dwarf is named WISE J085510.83-071442.5. It has a chilly temperature between minus 54 and 9 degrees Fahrenheit (minus 48 to minus 13 degrees Celsius). Previous record holders for coldest brown dwarfs, also found by WISE and Spitzer, were about room temperature.

WISE was able to spot the rare object because it surveyed the entire sky twice in infrared light, observing some areas up to three times. Cool objects like brown dwarfs can be invisible when viewed by visible-light telescopes, but their thermal glow -- even if feeble -- stands out in infrared light. In addition, the closer a body, the more it appears to move in images taken months apart. Airplanes are a good example of this effect: a closer, low-flying plane will appear to fly

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Herschel discovers mature galaxies in the young Universe

New Herschel results have given us a remarkable insight into the internal dynamics of two young galaxies. Surprisingly, they have shown that just a few billion years after the Big Bang, some galaxies were rotating in a mature way, seemingly having completed the accumulation of their gas reservoirs.

When galaxies form, they accumulate mass by gravitationally attracting vast, external gas clouds. As the gas clouds enter the galaxy, they fall into haphazard orbits. These disordered paths cause turbulence in the host galaxies, which can drive star formation.

To investigate the internal conditions of forming galaxies James Rhoads and Sangeeta Malhotra, both from Arizona State University, and colleagues targeted two young galaxies, known as S0901 and the Clone. The light from both galaxies has taken 10 billion years to reach us across space. Thus, we are seeing them when they were comparatively young.

"The purpose of this project is to study the physical conditions of gas in those galaxies. We wanted to know: are they similar to the galaxies around us or is there some difference in their physical conditions," says Rhoads.

The two galaxies they choose to study are average galaxies for that time in cosmic history. This means that they are about 10-20 per cent the size of our Milky Way, which is considered an average galaxy in the present-day Universe.

Studying galaxies so far away is usually hampered because they appear too dim to study effectively but in this case, the researchers were helped by a cosmic magnifier known as a gravitational lens. The two galaxies both sit behind intervening groups of galaxies, whose gravity warps space. As described by Albert Einstein’s General Theory of Relativity, this warping acts like a lens. Although it distorts the images of the young galaxies, it helps by magnifying their light, thus bringing them within reach of Herschel’s HIFI instrument.

The researchers used HIFI to investigate the infrared light of ionized carbon, which is emitted at a wavelength of 158 micrometres (a frequency of 1900 GHz). This spectral line is produced in the clouds that surround star-forming regions. HIFI showed the line was broadened into a double peak, and this allowed the motion of the gas to be fitted with a model.

Firstly, the team fitted the overall rotation of the galaxy, and then the turbulence in the gas clouds. To their surprise they found that galaxy S0901 was extremely well behaved. Instead of turbulence, it was found to be in orderly rotation, much more akin to the majestic galaxies of today.

"Usually, when astronomers examine galaxies at this early era, they find that turbulence plays a much greater role than it does in modern galaxies. But S0901 is a clear exception to that pattern, and the Clone could be another," says Rhoads.

The Clone, the second galaxy in their study, could also be fitted by an orderly rotation. However, because it was somewhat dimmer, the quality of the data was not so good. This meant that the data could also be fitted with a highly turbulent model, as conventional wisdom would expect.

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"Galaxies 10 billion years ago were making stars more actively than they do now," says Malhotra. "They usually also show more turbulence, likely because they are accumulating gas faster than a modern galaxy does. But here we have cases of early galaxies that combine the 'calm' rotation of a modern one with the active star formation of their early peers. This suggests first that these galaxies have finished accumulating their gas, at least for now. But it also seems that turbulence is not actually required to trigger that early, active star formation."

Malhotra acknowledges the preliminary nature of their study. "This is not the last word on this. We need a bigger sample to be sure of our conclusions," she says. But that bigger sample will not be investigated by Herschel. As predicted, the liquid helium coolant needed to keep HIFI and Herschel's other instruments working ran out in April 2013. Instead the researchers hope to continue the work pioneered by Herschel using the Atacama Large Millimeter/submillimeter Array (ALMA), a ground-based array of 66 radio dishes in Chile.

"It is mind-boggling that with Herschel/HIFI – admittedly with the help of gravitational lensing – it has been possible to study the internal gas kinematics in galaxies when the Universe was only a few billion years old, and what we can learn about them this way. This pioneering work by Herschel is bound to be continued," says Göran Pilbratt, Herschel Project Scientist at ESA.

The team wants to learn the more detailed structure and dynamics of Source I by using ALMA with higher resolution and sensitivity at higher frequency. Such observations should reveal the mysteries of the evolution of Source I. Hirota said, "It is also important that the physical conditions of a circumstellar disk depend on the mass of the central protostar. The circumstellar disk around a massive star is heated up to 3000 degrees Celsius. Dust that is the material for planets should melt away at such high temperatures. I wonder if planets can form under such condition. I'm interested in the dependence of planet formation on stellar mass and physical conditions."
ALMA Helps to Explain Massive Stars Mysterious Formation

A research team led by Tomoya Hirota (National Astronomical Observatory of Japan: NAOJ) discovered a hot circumstellar disk around a massive proto-star by using the Atacama Large Millimeter/Submillimeter Array (ALMA) and the VLBI Exploration of Radio Astrometry (VERA). The formation process of a massive star has been a long-standing problem. The research results favor disk accretion for the formation of massive stars, similar to the formation of low to intermediate mass stars such as the Sun.

The team observed a radio source called Source I in Orion KL, the nearest massive star-forming region. ALMA detected radio signals from hot water vapor with high angular resolution. The gas temperature reaches around 3000 degrees Celsius. Combining this data with the data taken by VERA, the team confirmed that the hot gas containing water vapor is actually a circumstellar disk around Source I. Thanks to an accurate estimated distance to Source I based on VERA observations, the disk diameter can be estimated at about 80 times larger than the distance between the Sun and Earth.

Thanks to recent intensive studies, the formation process of low to intermediate mass stars is now well understood. On the other hand, we know little about how massive stars form. Low and intermediate mass stars are formed by mass accretion from a circumstellar disk. Is this process the same for massive stars? Massive stars could form via stellar collisions as another theory suggests. We cannot answer such a simple question.

A radio telescope is essential to study the process of star formation because stars form in gas and dust, and a radio telescope observes such interstellar matter. For high resolution, observations by a radio array have a great advantage. Until very recently, the resolution and sensitivity of observational instruments were not high enough for detailed investigations of molecular clouds in which massive stars are forming. To make matters worse, most such clouds are located far from our Solar System. Now, ALMA enables researchers to study actual formation sites of massive stars.

The research team selected the nearest region of massive star-formation, Orion KL, for the ALMA observation. Stars with 8 times more mass than the Sun are forming in Orion KL. The distance to Orion KL is estimated to be about 1400 light-years, and it has been well studied since its discovery in 1967 because of its vicinity. The research team carried out observations of Source I in Orion KL with VERA. The team observed the launching point of a bipolar outflow, and found a cluster of vibrationally excited SiO masers tracing an outflow arising from the surface of the disk. The team uncovered a high-speed jet from the region surrounding Source I by observing the SiO masers. The other research group found a compact radio continuum source associated with the center of these vibrationally excited SiO masers. This radio source is interpreted as an edge-on disk. However, the nature of Source I is still controversial. The structure of this region is complex. Many large and small jets are blowing off in various directions. Thus, interpretation of the observations was sometimes different and some researchers deny the existence of the disk and jets.

Previously, the research team successfully found radio signals emitted by high temperature water vapor by analyzing ALMA’s data. When the data was taken, ALMA was in the science verification phase before full operation so the resolution was not high enough to uncover the nature of the molecular gas associated with the hot water vapor. Hirota, the leader of this study, said, “We proposed additional ALMA observations to understand Source I. We got very good quality data! The resolution is three times higher than the previous data set.” The team used the two radio lines emitted by water molecules at the frequencies of 321 GHz and 336 GHz, which are thought to correspond to gas temperatures of 1700 and 2700 degrees Celsius, respectively. Thus, these lines are suitable tracers to study the closest region of Source I. The team detected the two lines from the hot water molecules and clearly

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Jupiter's moon Ganymede may harbor 'club sandwich' of oceans and ice

The largest moon in our solar system, a companion to Jupiter named Ganymede, might have ice and oceans stacked up in several layers like a club sandwich, according to new NASA-funded research that models the moon's makeup. Previously, the moon was thought to harbor a thick ocean sandwiched between just two layers of ice, one on top and one on bottom.

"Ganymede's ocean might be organized like a Dagwood sandwich," said Steve Vance of NASA's Jet Propulsion Laboratory in Pasadena, Calif., explaining the moon's resemblance to the "Blondie" cartoon character's multi-tiered sandwiches. The study, led by Vance, provides new theoretical evidence for the team's "club sandwich" model, first proposed last year. The research appears in *Planetary and Space Science*. The results support the idea that primitive life might have possibly arisen on the icy moon. Scientists say that places where water and rock interact are important for the development of life; for example, it's possible life began on Earth in bubbling vents on our sea floor. Prior to the new study, Ganymede's rocky sea bottom was thought to be coated with ice, not liquid -- a problem for the emergence of life. The "club sandwich" findings suggest otherwise: the first layer on top of the rocky core might be salty water. "This is good news for Ganymede," said Vance. "Its ocean is huge, with enormous pressures, so it was thought that dense ice had to form at the bottom of the ocean. When we added salts to our models, we came up with liquids dense enough to sink to the sea floor."

NASA scientists first suspected an ocean in Ganymede in the 1970s, based on models of the large moon, which is bigger than Mercury. In the 1990s, NASA's Galileo mission flew by Ganymede, confirming the moon's ocean, and showing it extends to depths of hundreds of miles. The spacecraft also found evidence for salty seas, likely containing the salt magnesium sulfate. Previous models of Ganymede's oceans assumed that salt didn't change the properties of liquid very much with pressure. Vance and his team showed, through laboratory experiments, how much salt really increases the density of liquids under the extreme conditions inside Ganymede and similar moons. It may seem strange that salt can make the ocean denser, but you can see for yourself how this works by adding plain old table salt to a glass of water. Rather than increasing in volume, the liquid shrinks and becomes denser. This is because the salt ions attract water molecules.

The models get more complicated when the different forms of ice are taken into account. The ice that floats in your drinks is called "Ice I." It's the least dense form of ice and lighter than water. But at high pressures, like those in crushingly deep oceans like Ganymede's, the ice crystal structures become more compact. "It's like finding a better arrangement of shoes in your luggage -- the ice molecules become packed together more tightly," said Vance. The ice can become so dense that it is heavier than water and falls to the bottom of the sea. The densest and heaviest ice thought to persist in Ganymede is called "Ice VI." By modeling these processes using computers, the team came up with an ocean sandwiched between up to three ice layers, in addition to the rocky seafloor. The lightest ice is on top, and the saltiest liquid is heavy enough to sink to the bottom. What's more, the results demonstrate a possible bizarre phenomenon that causes the oceans to "snow upwards." As the oceans churn and cold plumes snake around, ice in the uppermost ocean layer, called "Ice III," could form in the seawater. When ice forms, salts precipitate out. The heavier salts would thus fall downward, and the lighter ice, or "snow," would float upward. This "snow" melts again before reaching the top of the ocean, possibly leaving slush in the middle of the moon sandwich. "We don't know how long the Dagwood-sandwich structure would exist," said Christophe Sotin of JPL. "This structure represents a stable state, but various factors could mean the moon doesn't reach this stable state.

Sotin and Vance are both members of the Icy Worlds team at JPL, part of the multi-institutional NASA Astrobiology Institute based at the Ames Research Center in Moffett Field, Calif. The results can be applied to exoplanets too, planets that circle stars beyond our sun. Some super-Earths, rocky planets more massive than Earth, have been proposed as "water worlds" covered in oceans. Could they have life? Vance and his team think laboratory experiments and more detailed modeling of exotic oceans might help find answers. Ganymede is one of five moons in our solar system thought to support vast oceans beneath icy crusts. The other moons are Jupiter's Europa and Callisto and Saturn's Titan and Enceladus. The European Space Agency is developing a space mission, called Jupiter ICy moons Explorer or JUICE, to visit Europa, Callisto and Ganymede in the 2030s. NASA and JPL are contributing to three instruments on the mission, which is scheduled to launch in 2022 (see [http://www.jpl.nasa.gov/news/news.php?release=2013-069](http://www.jpl.nasa.gov/news/news.php?release=2013-069)).
been referred to as "Planet X" or "Nemesis." In March of 2013, Luhman's analysis of the images from WISE uncovered a pair of much warmer brown dwarfs at a distance of 6.5 light years, making that system the third closest to the sun. His search for rapidly moving bodies also demonstrated that the outer solar system probably does not contain a large, undiscovered planet, which has been referred to as "Planet X" or "Nemesis."

"We wondered what happens when you catch a cluster in the midst of a major merger and how the merger process influences both the X-ray gas and the motion of the galaxies," explained John Hughes of Rutgers University. "So the bottom line is that because of the complicated merger state, it left some questions about the reliability of the mass estimates we were making."

"That's where the Hubble data came in," said Felipe Menanteau of the University of Illinois at Urbana-Champaign. "We were in dire need for an independent and more robust mass estimate given how extreme this cluster is and how rare its existence is in the current cosmological model. There was all this kinematic energy that could be unaccounted for and could potentially suggest that we were actually underestimating the mass." The expectation of "unaccounted energy" comes from the fact that the merger is occurring tangentially to the observers' line of sight. This means they are potentially missing a good fraction of the kinetic energy of the merger because their spectroscopic measurements only track the radial speeds of the galaxies.

The team used Hubble to measure how strongly the mass of the cluster warped space. Hubble's high resolution allowed measurements of so-called "weak lensing," where the cluster's immense gravity subtly distorts space like a funhouse mirror and warps images of background galaxies. The greater the warping, the more mass is locked up in the cluster. "What I did is basically look at the shapes of the background galaxies that are farther away than the cluster itself," explained Jee.

The team's next step with Hubble will be to try to get a large mosaic image of the cluster. It doesn't fit into Hubble's field of view. It's like looking at a giant's head and shoulders from the side, say researchers. "We can tell it's a pretty big El Gordo, but we don't know what kind of legs he has, so we need to have a larger field of view to get the complete picture of the giant," said Menanteau.