COMING EVENTS
PUBLIC OBSERVING
SUN. DEC. 07, 7:30 PM
Prairie Park Nature Center

DECEMBER Meeting
DEC 12, 2014, 7:30 PM
2001 Malott
New Horizons: 2015
Dr. Bruce Twarog, KU

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Report from the Officers
Our November monthly meeting was entertained and informed by San Diego State University astronomer Dr. Paul Etzel. Paul presented the basic outline of stellar evolution, while also providing insight into his own extensive research career analyzing and deciphering the complex evolution of interacting binary systems. 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. For December, we will have our annual holiday celebration, with an update on the New Horizons Mission to Pluto and the Kuiper Belt. NH is scheduled to arrive at Pluto in July 2015 after traveling for 9 years. If it works as planned, it will be revolutionize our understanding of the outer solar system and the increasingly complex system of trans-Neptunian objects epitomized by Pluto and Sedna. Note: thanks to our desire to avoid Thanksgiving weekend, our next public observing session is Sunday, Dec. 7 at 7:30 PM at Prairie Park Nature Center. Any suggestions for improving the club or the newsletter are always welcome.

Of Local Interest
Researcher Advances New Model for Dark Matter
Astrophysicists believe that about 80 percent of the substance of our universe is made up of mysterious “dark matter” that can’t be perceived by human senses or scientific instruments. Dark matter has not yet been detected in a lab. We infer about it from astronomical observations,” said Mikhail Medvedev, professor of physics and astronomy at the University of Kansas, who has just published breakthrough research on dark matter that merited the cover of Physical Review Letters, the world’s most prestigious journal of physics research. Medvedev proposes a novel model of dark matter, dubbed “flavor-mixed multicomponent dark matter.”

"Dark matter is some unknown matter, most likely a new elementary particle or particles beyond the Standard Model," Medvedev said. "It has never been observed directly, but it reveals itself via gravity it produces in the universe. There are numerous experiments around the world aimed at finding it directly.”

Medvedev’s theory rests on the behavior of elementary particles that have been observed or hypothesized. According to today’s prevalent Standard Model theory of particle physics, elementary particles — categorized as varieties of quarks, leptons and gauge bosons — are the building blocks of an atom. The properties, or “flavors,” of quarks and leptons are prone to change back and forth, because they can combine with each other in a phenomenon called flavor-mixing.

"In everyday life we’ve become used to the fact that each and every particle or an atom has a certain mass,” Medvedev said. “A flavor-mixed particle is weird — it has several masses simultaneously — and this leads to fascinating and unusual effects." Medvedev compared flavor-mixing to white light that contains several colors and can generate a rainbow.

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“If white was a particular flavor, then red, green and blue would be different masses — masses one, two and three — that mix up together to create white,” he said. “By changing proportions of red, green and blue in the mix, one can make different colors, or flavors, other than white.” Medvedev said that dark matter candidates are also theorized to be flavor-mixed — such as neutrinos, axions and sterile neutrinos.

“These are, in fact, the most preferred candidates people speak about all the time,” Medvedev said. “Previously we discovered that flavor-mixed particles can ‘quantum evaporate’ from a gravitational well if they are ‘shaken’ — meaning they collide with another particle,” he said. “That’s a remarkable result, as if a spacecraft made of flavor-mixed matter and hauled along a bumpy road puts itself into space without a rocket or any other means or effort by us.”

Medvedev included the physics process of quantum evaporation in a “cosmological numerical code” and performed simulations using supercomputers. “Each simulation utilized over a 1,000 cores and ran for a week or so,” he said. “This yearlong project consumed about 2 million computer hours in total, which is equal to 230 years.” Medvedev said that dark matter may interact with normal matter extremely weakly, which is why it hasn’t been revealed already in numerous ongoing direct detection experiments around the world. So physicists have devised a working model of completely collisionless (noninteracting), cold (that is, having very low thermal velocities) dark matter with a cosmological constant (the perplexing energy density found in the void of outer space), which they term the “Lambda-CDM model.”

But the model has hasn’t always agreed with observational data, until Medvedev’s paper solved the theory’s long-standing and troublesome puzzles. “Our results demonstrated that the flavor-mixed, two-component dark matter model resolved all the most pressing Lambda-CDM problems simultaneously,” said the KU researcher. Medvedev performed the simulations using XSEDE high-performance computation facilities, primarily Trestles at the San Diego Supercomputer Center and Ranger at the Texas Advanced Computing Center.

all directions from accelerating masses. If both black holes have equal masses and spins, their merger emits gravitational waves uniformly in all directions. More likely, the black hole masses and spins will be different, leading to lopsided gravitational wave emission that launches the black hole in the opposite direction.

The kick may be strong enough to hurl the black hole entirely out of its home galaxy, fating it to forever drift through intergalactic space. More typically, a kick will send the object into an elongated orbit. Despite its relocation, the ejected black hole will retain any hot gas trapped around it and continue to shine as it moves along its new path until all of the gas is consumed.

If SDSS1133 isn’t a black hole, then it might have been a very unusual type of star known as a Luminous Blue Variable (LBV). These massive stars undergo episodic eruptions that cast large amounts of mass into space long before they explode. Interpret ed in this way, SDSS1133 would represent the longest period of LBV eruptions ever observed, followed by a terminal supernova explosion whose light reached Earth in 2001.

The nearest comparison in our galaxy is the massive binary system Eta Carinae, which includes an LBV containing about 90 times the sun’s mass. Between 1838 and 1845, the system underwent an outburst that ejected at least 10 solar masses and made it the second-brightest star in the sky. It then followed up with a smaller eruption in the 1890s.

In this alternative scenario, SDSS1133 must have been in nearly continual eruption from at least 1950 to 2001, when it reached peak brightness and went supernova. The spatial resolution and sensitivity of telescopes prior to 1950 were insufficient to detect the source. But if this was an LBV eruption, the current record shows it to be the longest and most persistent one ever observed. An interaction between the ejected gas and the explosion’s blast wave could explain the object’s steady brightness in the ultraviolet. Whether it’s a rogue supermassive black hole or the closing act of a rare star, it seems astronomers have never seen the likes of SDSS1133 before.

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 rchjm@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/

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NASA's Swift mission probes an exotic object: 'Kicked' black hole or mega star?

An international team of researchers analyzing decades of observations from many facilities, including NASA's Swift satellite, has discovered an unusual source of light in a galaxy some 90 million light-years away.

The dwarf galaxy Markarian 177 (center) and its unusual source SDSS1133 (blue) lie 90 million light-years away. The galaxies are located in the bowl of the Big Dipper, a well-known star pattern in the constellation Ursa Major.

The object's curious properties make it a good match for a supermassive black hole ejected from its home galaxy after merging with another giant black hole. But astronomers can't yet rule out an alternative possibility. The source, called SDSS1133, may be the remnant of a massive star that erupted for a record period of time before destroying itself in a supernova explosion.

"With the data we have in hand, we can't yet distinguish between these two scenarios," said lead researcher Michael Koss, an astronomer at ETH Zurich, the Swiss Federal Institute of Technology. "One exciting discovery made with NASA's Swift is that the brightness of SDSS1133 has changed little in optical or ultraviolet light for a decade, which is not something typically seen in a young supernova remnant."

In a study published in the Nov. 21 edition of *Monthly Notices of the Royal Astronomical Society*, Koss and his colleagues report that the source has brightened significantly in visible light during the past six months, a trend that, if maintained, would bolster the black hole interpretation. To analyze the object in greater detail, the team is planning ultraviolet observations with the Cosmic Origins Spectrograph aboard the Hubble Space Telescope in October 2015.

Whatever SDSS1133 is, it's persistent. The team was able to detect it in astronomical surveys dating back more than 60 years.

The mystery object is part of the dwarf galaxy Markarian 177, located in the bowl of the Big Dipper, a well-known star pattern within the constellation Ursa Major. Although supermassive black holes usually occupy galactic centers, SDSS1133 is located at least 2,600 light-years from its host galaxy's core.

In June 2013, the researchers obtained high-resolution near-infrared images of the object using the 10-meter Keck II telescope at the W. M. Keck Observatory in Hawaii. They reveal the emitting region of SDSS1133 is less than 40 light-years across and that the center of Markarian 177 shows evidence of intense star formation and other features indicating a recent disturbance.

"We suspect we're seeing the aftermath of a merger of two small galaxies and their central black holes," said co-author Laura Blecha, an Einstein Fellow in the University of Maryland's Department of Astronomy and a leading theorist in simulating recoils, or "kicks," in merging black holes. "Astronomers searching for recoiling black holes have been unable to confirm a detection, so finding even one of these sources would be a major discovery."

The collision and merger of two galaxies disrupts their shapes and results in new episodes of star formation. If each galaxy possesses a central supermassive black hole, they will form a bound binary pair at the center of the merged galaxy before ultimately coalescing themselves.

Merging black holes release a large amount of energy in the form of gravitational radiation, a consequence of Einstein's theory of gravity. Waves in the fabric of space-time ripple outward in...
Where the Heavenliest of Showers Come From

By Dr. Ethan Siegel

You might think that, so long as Earth can successfully dodge the paths of rogue asteroids and comets that hurtle our way, it's going to be smooth, unimpeded sailing in our annual orbit around the sun. But the meteor showers that illuminate the night sky periodically throughout the year not only put on spectacular shows for us, they're direct evidence that interplanetary space isn't so empty after all!

When comets (or even asteroids) enter the inner solar system, they heat up, develop tails, and experience much larger tidal forces than they usually experience. Small pieces of the original object—often multiple kilometers in diameter—break off with each pass near the sun, continuing in an almost identical orbit, either slightly ahead-or-behind the object's main nucleus. While both the dust and ion tails are blown well off of the main orbit, the small pieces that break off are stretched, over time, into a diffuse ellipse following the same orbit as the comet or asteroid it arose from. And each time the Earth crosses the path of that orbit, the potential for a meteor shower is there, even after the parent comet or asteroid is completely gone!

This relationship was first uncovered by the British astronomer John Couch Adams, who found that the Leonid dust trail must have an orbital period of 33.25 years, and that the contemporaneously discovered comet Tempel-Tuttle shared its orbit. The most famous meteor showers in the night sky all have parent bodies identified with them, including the Lyrids (comet Thatcher), the Perseids (comet Swift-Tuttle), and what promises to be the best meteor shower of 2014: the Geminids (asteroid 3200 Phaethon). With an orbit of only 1.4 years, the Geminids have increased in strength since they first appeared in the mid-1800s, from only 10-20 meteors per hour up to more than 100 per hour at their peak today! Your best bet to catch the most is the night of December 13th, when they ought to be at maximum, before the Moon rises at about midnight.

The cometary (or asteroidal) dust density is always greatest around the parent body itself, so whenever it enters the inner solar system and the Earth passes near to it, there's a chance for a meteor storm, where observers at dark sky sites might see thousands of meteors an hour! The Leonids are well known for this, having presented spectacular shows in 1833, 1866, 1966 and a longer-period storm in the years 1998-2002. No meteor storms are anticipated for the immediate future, but the heavenliest of showers will continue to delight skywatchers for all the foreseeable years to come!

ASTRONOMY ASSOCIATES of LAWRENCE

NEW HORIZONS 2015

Dr. Bruce Twarog
University of Kansas

FRIDAY, DECEMBER 12, 2014
2001 Malott
7:30 PM
Free and Open to the Public
A Colorful Gathering of Middle-aged Stars

NGC 3532 is a bright open cluster located some 1300 light-years away in the constellation of Carina (The Keel of the ship Argo). It is informally known as the Wishing Well Cluster, as it resembles scattered silver coins which have been dropped into a well. It is also referred to as the Football Cluster, although how appropriate this is depends on which side of the Atlantic you live. It acquired the name because of its oval shape, which citizens of rugby-playing nations might see as resembling a rugby ball.

This very bright star cluster is easily seen with the naked eye from the southern hemisphere. It was discovered by French astronomer Nicolas Louis de Lacaille whilst observing from South Africa in 1752 and was catalogued three years later in 1755. It is one of the most spectacular open star clusters in the whole sky.

NGC 3532 covers an area of the sky that is almost twice the size of the full Moon. It was described as a binary-rich cluster by John Herschel who observed “several elegant double stars” here during his stay in southern Africa in the 1830s. Of additional, much more recent, historical relevance, NGC 3532 was the first target to be observed by the NASA/ESA Hubble Space Telescope, on 20 May 1990.

This grouping of stars is about 300 million years old. This makes it middle-aged by open star cluster standards.

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Researchers using NASA's Hubble Space Telescope and Chandra X-ray Observatory have uncovered young, massive, compact galaxies whose raucous star-making parties are ending early. The firestorm of star birth has blasted out most of the remaining gaseous fuel needed to make future generations of stars. Now the party's over for these gas-starved galaxies, and they are on track to possibly becoming so-called "red and dead galaxies," composed only of aging stars.

Astronomers have debated for decades how massive galaxies rapidly evolve from active star-forming machines to star-starved graveyards. Previous observations of these galaxies reveal geysers of gas shooting into space at up to 2 million miles an hour. Astronomers have suspected that powerful monster black holes lurking at the centers of the galaxies triggered the gaseous outflows and shut down star birth by blowing out any remaining fuel. Now an analysis of 12 merging galaxies at the end of their star-birthing frenzy is showing that the stars themselves are turning out the lights on their own star-making party. This happened when the universe was half its current age of 13.7 billion years.

"Before our study, the common belief was that stars cannot drive high-velocity outflows in galaxies; only more powerful supermassive black holes can do that," explained Paul Sell of Texas Tech University in Lubbock, lead author of a science paper describing the study's results. "Through our analysis we found that if you have a compact enough starburst, which Hubble showed was the case with these galaxies, you can actually produce the velocities of the outflows we observed from the stars alone without needing to invoke the black hole."

Team member Christy Tremonti of the University of Wisconsin-Madison first identified the galaxies from the Sloan Digital Sky Survey as post-starburst objects spouting high-speed gaseous fountains. The sharp visible-light views from Hubble's Wide Field Camera 3 show that the outflows are arising from the most compact galaxies yet found. These galaxies contain as much mass as our Milky Way galaxy, but packed into a much smaller area. The smallest galaxies are about 650 light-years across. In such small regions of space, these galaxies are forming a few hundred suns a year. (By comparison, the Milky Way makes only about one sun a year.) This makes for a rowdy party that wears itself out quickly, in only a few tens of millions of years. One reason for the stellar shutdown is that the gas rapidly heats up, becoming too hot to contract under gravity to form new stars. Another possibility is that the star-birthing frenzy blasts out most of the star-making gas via powerful stellar winds.

"The biggest surprise from Hubble was the realization that the newly formed stars were born so close together," said team member Aleks Diamond-Stanic of the University of Wisconsin-Madison, who first suggested the possibility of starburst-driven outflows from these galaxies in a 2012 science paper. "The extreme physical conditions at the centers of these galaxies explain how they can expel gas at millions of miles per hour."

To identify the mechanism triggering the high-velocity outflows, Sell and his team used the Chandra X-ray Observatory and other telescopes to determine whether the galaxies' supermassive black holes (weighing up to a billion suns) were the powerhouses driving them. After analyzing all of the observations, the team concluded that the black holes were not the source of the outflows. Rather, it was the powerful stellar winds from the most massive and short-lived stars at the end of their lives, combined with their explosive deaths as supernovae. Based on their analysis of the Hubble and Chandra data, team members suggest that the "party begins" when two gas-rich galaxies collide, funneling a torrent of cold gas into the merging galaxies' compact center. The large amount of gas compressed into the small space ignites the birth of numerous stars. The energy from the stellar firestorm then blows out the leftover gas, quenching further star formation.

"If you stop the flow of cold gas to form stars, that's it," explained Sell, who conducted the research while a graduate student at the University of Wisconsin-Madison. "The stars stop forming, and the galaxy rapidly evolves and may eventually become a red, dead elliptical galaxy. These extreme starbursts are quite rare, however, so they may not grow into the typical giant elliptical galaxies seen in our nearby galactic neighborhood. They may, instead, be more compact."
A team led by the University of Colorado Boulder has discovered an invisible shield some 7,200 miles above Earth that blocks so-called "killer electrons," which whip around the planet at near-light speed and have been known to threaten astronauts, fry satellites and degrade space systems during intense solar storms.

The barrier to the particle motion was discovered in the Van Allen radiation belts, two doughnut-shaped rings above Earth that are filled with high-energy electrons and protons, said Distinguished Professor Daniel Baker, director of CU-Boulder's Laboratory for Atmospheric and Space Physics (LASP). Held in place by Earth's magnetic field, the Van Allen radiation belts periodically swell and shrink in response to incoming energy disturbances from the sun.

As the first significant discovery of the space age, the Van Allen radiation belts were detected in 1958 by Professor James Van Allen and his team at the University of Iowa and were found to be composed of an inner and outer belt extending up to 25,000 miles above Earth's surface. In 2013, Baker -- who received his doctorate under Van Allen -- led a team that used the twin Van Allen Probes launched by NASA in 2012 to discover a third, transient "storage ring" between the inner and outer Van Allen radiation belts that seems to come and go with the intensity of space weather.

The latest mystery revolves around an "extremely sharp" boundary at the inner edge of the outer belt at roughly 7,200 miles in altitude that appears to block the ultrafast electrons from breeching the shield and moving deeper towards Earth's atmosphere.

"It's almost like theses electrons are running into a glass wall in space," said Baker, the study's lead author. "Somewhat like the shields created by force fields on Star Trek that were used to repel alien weapons, we are seeing an invisible shield blocking these electrons. It's an extremely puzzling phenomenon."

A paper on the subject was published in the Nov. 27 issue of Nature.

The team originally thought the highly charged electrons, which are looping around Earth at more than 100,000 miles per second, would slowly drift downward into the upper atmosphere and gradually be wiped out by interactions with air molecules. But the impenetrable barrier seen by the twin Van Allen belt spacecraft stops the electrons before they get that far, said Baker.

The group looked at a number of scenarios that could create and maintain such a barrier. The team wondered if it might have to do with Earth's magnetic field lines, which trap and control protons and electrons, bouncing them between Earth's poles like beads on a string. The also looked at whether radio signals from human transmitters on Earth could be scattering the charged electrons at the barrier, preventing their downward motion. Neither explanation held scientific water, Baker said.

"Nature abhors strong gradients and generally finds ways to smooth them out, so we would expect some of the relativistic electrons to move inward and some outward," said Baker. "It's not obvious how the slow, gradual pro-

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Hubble Surveys Debris-Strewn Exoplanetary Construction Yards

Astronomers using NASA's Hubble Space Telescope have completed the largest and most sensitive visible-light imaging survey of dusty debris disks around other stars. These dusty disks, likely created by collisions between leftover objects from planet formation, were imaged around stars as young as 10 million years old and as mature as more than 1 billion years old.

"It's like looking back in time to see the kinds of destructive events that once routinely happened in our solar system after the planets formed," said survey leader Glenn Schneider of the University of Arizona's Steward Observatory. The survey's results appeared in the Oct. 1, 2014, issue of The Astronomical Journal.

Once thought to be simply pancake-like structures, the unexpected diversity and complexity of these dusty debris structures strongly suggest they are being gravitationally affected by unseen planets orbiting the star. Alternatively, these effects could result from the stars' passing through interstellar space.

The researchers discovered that no two "disks" of material surrounding stars look the same. "We find that the systems are not simply flat with uniform surfaces," Schneider said. "These are actually pretty complicated three-dimensional debris systems, often with embedded smaller structures. Some of the substructures could be signposts of unseen planets."

The astronomers used Hubble's Space Telescope Imaging Spectrograph to study 10 previously discovered circumstellar debris systems, plus MP Mus (a mature protoplanetary disk of age comparable to the youngest of the debris disks).

Irregularities observed in one ring-like system in particular, around a star called HD 181327, resemble the ejection of a huge spray of debris into the outer part of the sys-

(Continued on page 10)
cesses that should be involved in motion of these particles can conspire to create such a sharp, persistent boundary at this location in space."

Another scenario is that the giant cloud of cold, electrically charged gas called the plasmasphere, which begins about 600 miles above Earth and stretches thousands of miles into the outer Van Allen belt, is scattering the electrons at the boundary with low frequency, electromagnetic waves that create a plasmaspheric "hiss," said Baker. The hiss sounds like white noise when played over a speaker, he said.

While Baker said plasmaspheric hiss may play a role in the puzzling space barrier, he believes there is more to the story. "I think the key here is to keep observing the region in exquisite detail, which we can do because of the powerful instruments on the Van Allen probes. If the sun really blasts Earth's magnetosphere with a coronal mass ejection (CME), I suspect it will breach the shield for a period of time," said Baker, also a faculty member in the astrophysical and planetary sciences department.

"It's like looking at the phenomenon with new eyes, with a new set of instrumentation, which give us the detail to say, "Yes, there is this hard, fast boundary,"" said John Foster, associate director of MIT's Haystack Observatory and a study co-author.

The cluster stars that started off with moderate masses are still shining brightly with blue-white colours, but the more massive ones have already exhausted their supplies of hydrogen fuel and have become red giant stars. As a result the cluster appears rich in both blue and orange stars. The most massive stars in the original cluster will have already run through their brief but brilliant lives and exploded as supernovae long ago. There are also numerous less conspicuous fainter stars of lower mass that have longer lives and shine with yellow or red hues. NGC 3532 consists of around 400 stars in total.

The background sky here in a rich part of the Milky Way is very crowded with stars. Some glowing red gas is also apparent, as well as subtle lanes of dust that block the view of more distant stars. These are probably not connected to the cluster itself, which is old enough to have cleared away any material in its surroundings long ago.

"This spray of material is fairly distant from its host star — roughly twice the distance that Pluto is from the Sun," said co-investigator Christopher Stark of NASA's Goddard Space Flight Center, Greenbelt, Maryland.

"Catastrophically destroying an object that massive at such a large distance is difficult to explain, and it should be very rare. If we are in fact seeing the recent aftermath of a massive collision, the unseen planetary system may be quite chaotic."

Another interpretation for the irregularities is that the disk has been mysteriously warped by the star's passage through interstellar space, directly interacting with unseen interstellar material. "Either way, the answer is exciting," Schneider said. "Our team is currently analyzing follow-up observations that will help reveal the true cause of the irregularity."

Over the past few years astronomers have found an incredible diversity in the architecture of exoplanetary systems — planets are arranged in orbits that are markedly different than found in our solar system. "We are now seeing a similar diversity in the architecture of accompanying debris systems," Schneider said. "How are the planets affecting the disks, and how are the disks affecting the planets? There is some sort of interdependence between a planet and the accompanying debris that might affect the evolution of these exoplanetary debris systems."

From this small sample, the most important message to take away is one of diversity, Schneider said. He added that astronomers really need to understand the internal and external influences on these systems, such as stellar winds and interactions with clouds of interstellar material, and how they are influenced by the mass and age of the parent star, and the abundance of heavier elements needed to build planets.

Though astronomers have found nearly 4,000 exoplanet candidates since 1995, mostly by indirect detection methods, only about two dozen light-scattering, circumstellar debris systems have been imaged over that same time period. That's because the disks are typically 100,000 times fainter than, and often very close to, their bright parent stars. The majority have been seen because of Hubble's ability to perform high-contrast imaging, in which the overwhelming light from the star is blocked to reveal the faint disk that surrounds the star. The new imaging survey also yields insight into how our solar system formed and evolved 4.6 billion years ago. In particular, the suspected planet collision seen in the disk around HD 181327 may be similar to how the Earth-Moon system formed, as well as the Pluto-Charon system over 4 billion years ago. In those cases, collisions between planet-sized bodies cast debris that then coalesced into a companion moon.