"The Southern Cross"

HERMANUS ASTRONOMY CENTRE NEWSLETTER

JULY 2017

Change of meeting venue Please note that the Scout Hall is longer the venue for Centre meetings. From July 2017, these will take place at the neighbouring **Catholic Church Hall** (the venue for U3A meetings). The Catholic Hall is in the block on the mountain side of the Scout Hall. Parking is available to the side of the building or across the road.

This month's Centre meeting
This will take place on **Monday 17 July** at the **Catholic Hall** starting at **19.00**. Auke Slotegraaf will be talking on 'Deep sky stargazing'. See below for more details.

WHAT'S UP?

A visiting messenger Soon after sunset, Mercury (the winged messenger in Roman mythology) can be seen to the north-west this month. It is in the region of the constellation of Leo, although this will only become visible after dark. Like Venus, the other planet which orbits between the Earth and the Sun, Mercury has phases. However, due to its small size, these are difficult to observe. Mercury is an unusual planet. The closest planet to the Sun (average 58 million km) and the smallest of the major planets (diameter around 5,000 km v Earth's 12,750 km), Mercury has the most elliptical of the planetary orbits. It also has the greatest temperature ranges of the planets; »450°C during the day at its closest position to the Sun to around -180°C during the coldest nights. Proximity to the Sun has almost destroyed its atmosphere and its surface is pockmarked with impact craters. Its unusually high density suggests that 70% of Mercury is made of iron, probably concentrated in a large core. It has almost no tilt from the vertical, so no seasons. Also, the fact that one rotation (a day) of Mercury takes 58.6 days and one Merciruan year lasts 88 days means that this little planet takes three days to complete two orbits around the Sun. These timings produce a confusing pattern of partial sun rises and sets, some occurring several times in a day.

LAST MONTH'S ACTIVITIES

Monthly centre meeting Centre member, Johan Retief very kindly stepped in to give the presentation on 19 June, when the scheduled presenter had to cancel. He gave a talk on 'Mars: exploring the red planet', an updated version of the excellent talk he gave on this topic to U3A earlier in the year. He noted that no human has ventured into space beyond the Hubble Space Telescope since the last Moon landing in 1972, 45 years ago.

Human space travel is being planned again, but, this time, the purpose is much more ambitious: to land, stay and, potentially, even settle on Mars. Against this background, Johan summarised the history of Earth-based study of Mars incl observation, by some, of canals on its surface, NASA's Mars exploration program, past and current spacecraft and robotic exploration of Mars, and, building on what has been learned about the red planet from these missions, planned future missions aimed at ultimately enabling humans to land on Mars. In his excellent presentation, Johan also summarised the physical, physiological and psychological challenges involved for lifeforms not adapted to living on a planet other than Earth, and outlined the missions planned by NASA to enable a manned missions to Mars. Finally, he noted that some private space companies also have plans to send humans to Mars.

Interest groups

Cosmology 17 people (16 members, 1 visitor) attended the meeting on 5 June. They watched another two episodes in the DVD series: Particle Physics for Non-Physicists: a Tour of the Microcosmos' by Prof Steven Pollock, Professor of physics at the University of Colorado at Boulder. These episodes were Lecture 9 'The particle zoo' and Lecture 10 'Fields and forces'.

Astro-photography At the meeting on 12 June, members continued to work on processing their own astro-images.

Other activities

Educational outreach

Hawston Secondary School Astronomy Group The final meetings with the Grade 12 space cadets took place this month.

Lukhanyo Youth Club No meetings are being arranged while members are attending a series of workshops being run by SANSA staff during 2017.

THIS MONTH'S ACTIVITIES

Monthly centre meeting This month's meeting will take place on **Monday 17 July** at the **Catholic Hall** starting at **19.00**. Auke Slotegraaf, psychohistorian and editor of the Sky Guide for Africa South will be talking on 'Deep sky stargazing'. A very knowledgeable and experienced astronomical observer, Auke will focus on deep sky objects, sharing his extensive experience and insights into observing the wonders of the stars, nebulae, clusters and galaxies which can be found beyond the solar system

There is an entrance fee of R10 per person for members, R20 per person for non-members, and R10 for children, students and U3A members.

Interest group meetings

The **Cosmology** group meets on the first Monday of each month at 19.00. This month's meeting will take place on **3 July** at the **Catholic Hall**, starting at **19.00**. Attendees will watch the next two episodes in the DVD series: Particle Physics for Non-Physicists: a Tour of the Microcosmos' by by Prof Steven Pollock, Professor of physics at the University of Colorado at Boulder. The content will be Lecture 11: 'Three quarks for Muster Mark' and Lecture 12: 'From quarks to QCD'.

There is an entrance fee of R10 per person for members, R20 per person for non-members, and R10 for children, students and U3A members. For further information on these meetings, or any of the group's activities, please contact Pierre Hugo at pierre@hermanus.co.za

Astro-photography This group meets on the third Monday of each month. The next meeting is on **10 July**. Members will continue work on processing their own astro-images.

To find out more about the group's activities and the venue for particular meetings, please contact Deon Krige at astronomy.hermanus@gmail.com

Hermanus Youth Robotic Telescope Interest Group Organisers continue to work towards accessing images which learners can start processing with suitable software.

For further information on both the MONET and Las Cumbres projects, please contact Deon Krige at deonk@telkomsa.net

Stargazing In recognition of probable adverse winter weather conditions, no events will take place in July.

FUTURE ACTIVITIES

Possible trips for 2017 are being considered. Details will be circulated to members when arrangements have been made.

2017 MONTHLY MEETINGS

Unless stated otherwise, meetings take place on the **third Monday** of each month at the **Catholic Church Hall**, beginning at 19.00.

17 July	'Deep sky stargazing' Presenter: Auke Slotegraaf, psychohisotiran and editor of the Sky Guide
21 Aug	Topic to be confirmed. Presenter: Dr Amanda Sickafoose, SAAO, CT
18 Sept	'Hidden features: discovering space in a reluctant Universe' Presenter: Dr Michelle Cluver, UCT
16 Oct	'Jupiter: the neighbourhood bully' Presenter: Jenny Morris, Committee member
20 Nov	TBA
11 Dec	Xmas party

ASTRONOMY EDUCATION CENTRE AND AMPHITHEATRE (AECA)

Additional information requested by staff at Overstrand Municipality has been submitted. Hopefully, this will enable the Council to consider the planning application within a month or two. In the meantime, the Friends of the Observatory pledge fund continues to be an important source of funds to cover associated costs.

The **Friends of the Observatory campaign** was launched several years ago when preliminary work began on plans to construct an astronomical observatory in Hermanus. Over the years, members have been very generous, for which we are deeply grateful. It may seem logical to assume that, now money has been awarded by the National Lotteries Board, pledge monies are no longer needed. Unfortunately, that is not the case. NLC funds can only be used once the plans have been formally approved by the Municipality, something which is still awaited.

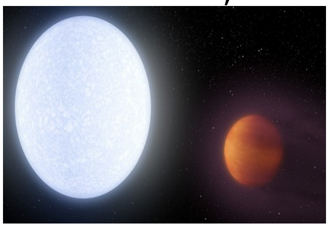
We would, therefore, be very grateful if members could either continue to contribute to the campaign or start becoming a contributor. Both single donations and small, regular monthly donations, of any amount, are welcome. Contributions can take the form of cash (paid at meetings), or online transfer, The Standard Bank details are as follows:

Account name – Hermanus Astronomy Centre
Account number – 185 562 531
Branch code – 051001

If you make an online donation, please include the word 'pledge', and your name, unless you wish to remain anonymous.

ASTRONOMY NEWS

We have just found the hottest gas giant ever 6 June: Astronomers with the Kilodegree Extremely Little Telescope(s) (KELT) survey have just announced an amazing find: the hottest gas giant ever discovered. In fact, the planet is so hot that it is hotter than most stars, and it is only a few thousand degrees cooler than our own Sun.


KELT-9b is the hottest gas giant ever detected. It orbits a hot, young star more than twice as massive as our Sun NASA/JPL-Caltech

The planet, KELT-9b, is about three times the mass of Jupiter and twice its size. Its discovery was announced by B. Scott Gaudi of The Ohio State University and Karen Collins of Vanderbilt University "We are very excited today to announce the discovery of KELT-9b … a gas giant planet hotter than most stars. And I want to emphasise that's not a typo," Collins said. She went on to explain that KELT-9b is so hot because of its sun, "the brightest, hottest, most massive known transiting gas giant planet host star."

That host star is roughly 2.5 times the mass of our Sun, and is rotating so quickly (about once a day) that it is more of a flattened egg shape than a sphere, like the planet Saturn. Every time KELT-9b transits across the face of its sun, the light coming from the star drops by only one half of one percent. The star, which is a hot, blue star, radiates not only in the optical, but also puts out huge amounts of ultraviolet (UV) light. Its massive output, coupled with KELT-9b's close proximity, boosts the temperature on the planet's day side to about 4,300ºC. Because the planet is tidally locked, the same side always faces its parent star; astronomers currently think that the night side is much cooler, due to the atmosphere's poor ability to transfer heat from the broiling day side to the rest of the planet. Even still, that 'cool' side is hot: "The night side would probably look like a red dwarf to our eyes," Gaudi said.

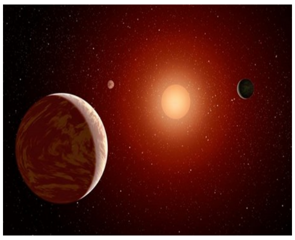
Furthermore, KELT-9b is orbiting its star perpendicular to the host's axis of rotation. That means rather than circling in the same plane as the stars equator, as our planets circle the Sun, KELT-9b flies over its parent stars north and south poles with every 1.5-day orbit it completes. This odd orbit, Gaudi said, likely precesses as well, which means the planet may stop transiting its sun as seen from Earth within about 150 years, depending on the rate of this precession. Astronomers would then have to wait several thousand years before transits could be seen again.

However, one of the oddest things about KELT-9b may be the fact that it is evaporating. Its parent star puts out so much UV radiation (700 times more than the UV radiation imparted on any other known gas giant) that “the planet is almost certainly being evaporated by the high-energy photons,” explained Gaudi. Although there is no firm measurement of how fast it is losing gas, Gaudi went on to say that KELT-9b could be shedding its atmosphere at a rate between 10 billion and 10 trillion grams per second. As a result, the planet likely sports a comet-like tail as it zips around its sun.

Whether the planet will fully evaporate before its host star expands into its red giant phase is unknown. Either way, Keivan Stassun, part of the discovery team and a professor of physics and astronomy at Vanderbilt University, said, “The long-term prospects for life, or real estate for that matter, on KELT-9b are not looking good.” Maybe not, but the system is still intriguing and, as of right now, unique. “It’s going to be a great system for us to study with HST, Spitzer, and eventually [the] James Webb Space Telescope, not to mention ground-based facilities.” said Gaudi. “We’re really looking forward to trying to characterize the properties of this planet and understand it better.”

The KELT survey focuses primarily on bright stars because the telescopes it uses are small. Half of its target stars are both hotter and more massive than the Sun, a parameter space not typically explored by other exoplanet searches. Thus, KELT-9b may only be the first of many extremely hot gas giants this survey turns up. By: Alison Klesman

Do stellar flares damage exoplanets? 7 June: Cool stars have really come into their own lately, especially as discoveries of their planetary systems increase (think TRAPPIST-1 and Proxima Centauri). However, despite their relatively cool nature, these stars can put out intense flares that might affect the planets haplessly circling them. The role of such flares remains unknown, but maybe not for long, now that a team of astronomers has begun building a database of dwarf star flares from high-precision data obtained by the Galaxy Evolution Explorer (GALEX) mission.


Planets circling a red dwarf sun could be at the mercy of these stars’ frequent flares. NASA/JPL-Caltech

The database was introduced at the 230th Meeting of the American Astronomical Society by Chase Million of Million Concepts. Million is the leader of a project called gPhoton, which has undertaken the effort to reprocess data taken by GALEX, which recorded the sky in ultraviolet (UV) light. Thus far, the team has examined more than 100 terabytes of data, looking for flares from red dwarf stars. Although these stars are normally unremarkable in the UV bands, the flares they emit cause them to brighten and become noticeable at these wavelengths, if only for a short time. “The foundation of this work is the observation that the sky changes rapidly,” said Million.

While large flares are easier to record, smaller flares have also been seen – and they are predicted to occur more frequently. It is these smaller flares that Million and his colleagues are looking to identify, thanks to the remarkably high precision (5 thousandths of a second) of the data taken by GALEX. Finding these rapid flares is now possible with the help of gPhoton, which allows astronomers to “unlock that very short time domain data” and “study very fast variables with archival data,” he said.

The gPhoton database is now a trillion photons strong and 1.2 terabytes in size. It currently comprises 10,000 m-dwarf stars with known distances, and each star has its own light curve (a measurement of the amount of light it emits over time). From these light curves, the team has already identified 100 to 200 small flares, each about a minute in length, "at energies that haven't really been measured before," said Million.

And these flares could have serious implications for planets around these cool stars. "Habitable planets are closer to cooler stars and cooler stars, we know, have a lot of these flares. Even though small flares are small, because the planets are closer, they will have more of an impact on the habitability of those planets." Million said, "It may be that flares strip away the atmospheres and maybe that they irradiate the surfaces. There's even a recent preprint where they say … some amount of flare activity may be necessary for prebiotic chemistry. I don't know, but I'm really excited to get this result out so that other people can tell me what it means." By: Alison Klesman

Galaxies are locked in place by their surroundings 13 June: Galaxies can be used as tracers for numerous characteristics of the universe, including the 'cosmic web' of hydrogen gas that connects galaxies and follows the distribution of dark matter filaments throughout the cosmos. Looking at where galaxies sit sheds light on these otherwise invisible structures, while also providing clues about the amount of mass in galaxies and how they influence their neighbours over time. Now, astronomers have traced the alignment of massive galaxies back 10 billion years, showing these objects have been in tune with their environment since the universe was just one-third its current age.


Also known as Pandora's Cluster, Abell 2744 is home to numerous bright elliptical galaxies in its centrer. NASA,ESA, and J. Lotz, M. Mountain, A. Koekemoer, and the HFF Team (STScI)

The work was led by Lowell Observatory astronomer Michael West, who together with his collaborators used Hubble Space Telescope images of 65 galaxy clusters located billions of light-years away to study the orientation of the massive elliptical galaxies in the centrers of these clusters. What they found suggests that the biggest, brightest galaxies in galaxy clusters have been heavily influenced by their unique environment since very early times.

Galaxy clusters present a very different environment from 'the field', which is an astronomer's term for the majority of the sky, which shows no preferential structure or clustering of galaxies. Inside galaxy clusters, individual galaxies are subjected to intense gravity, a hot intracluster medium of gas, and many more 'flybys' between neighbouring galaxies than could ever occur in the less dense field. And while galaxies in the field tend to be oriented any which way, galaxies in clusters are different. The massive galaxies at the centrers of clusters show preferential alignment with their neighbours, and astronomers are still looking to find out why.

One reason for this alignment could be that over time, gravity simply tends to orient large galaxies in the same direction as their neighbours. Alternatively, because large galaxies grow by absorbing smaller galaxies, these smaller galaxies could impart orientation on the galaxies that eat them due to the progenitors' preferred orientation along the cosmic web. The results of West's study do not rule out either scenario, but they do help constrain the alignment by showing that it occurs very early on in galaxy evolution. "It's an important new piece of the puzzle," said West, "because it says that whatever caused these alignments happened early."

What's next? West's group plans to push the envelope further by trying to observe even more distant galaxies. Despite the precision achievable with Hubble, however, this will be challenging, as even massive galaxies appear fainter and smaller as the distance between Earth and these clusters grows. However, such observations at the earliest epochs may help astronomers finally determine the reason for this preferred orientation, helping to complete our picture of early galaxy evolution. By: Alison Klesman

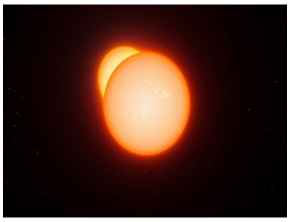
Jupiter has two new moons 14 June: While on the hunt for Planet X, DTM staff scientist Scott Sheppard, along with David Tholen from the University of Hawaii and Chadwick Trujillo from Northern Arizona University, decided to point their telescopes toward Jupiter. From there, the team could study Jupiter in the foreground while continuing their search for Planet X in the background. While making those observations, they discovered many 'lost moons in addition to two new, mile-wide moons they are calling S/2016 J 1 and S/2017 J 1. The new moons lie about 21 million km and 24 million km from Jupiter.


A montage of images taken by Voyager of Jupiter and four of its moons: Io, Europa, Ganymede, and Callisto. NASA/JPL

Several of the moons Sheppard's team found qualify as lost moons. Despite their discovery back in 2003, there was not enough information to define their exact orbits, so astronomers lost track of them as they circled Jupiter. Some moons have been found since that time, but at the beginning of 2016, 14 were still considered lost. While observing, Sheppard and his team added their data from 2016-2017 to data from 2003 and found five of those lost moons. They will continue observing for another year to see if they can identify the rest of the lost moons; they may find more new moons, too.

In the meantime, after checking their 2016-2017 data against images taken in 2003, the team confirmed that S/2016 J 1 and S/2017 J 1 are previously undiscovered moons, bringing the number of Jupiter's moons up to 69. By: Nicole Kiefert

Stars may all be born in pairs and lose their siblings later 15 June: Our poor, lonely Sun. A cloud of gas and young stars in the Perseus molecular cloud may be revealing a strange truth to the Universe: most, if not all, stars are born in pairs. This means that somewhere out there, the Sun has a lost companion — and it may be one of several known stars.

 All stars might form in multiple-star systems, and simply drift apart - or fling their partners away - over time. European Southern Observatory/L. Calcada

Essentially, all stars form in molecular clouds. In the Perseus observations, nearly all of these stars were gravitationally bound. This may be a requirement of protostars — the egg-like objects could require a common centre of gravity with a companion to accumulate mass. The dense cores then use leftover material to form more stars, continuing the process.

So why does the Sun not have a binary companion? It seems that 60 percent of stars shed their binary sister over time, gaining a wider distance from their partner until they are gravitationally severed. They also may not all have the same symmetry with regard to mass, meaning that some former companions could be brown dwarfs cast out by larger stars. The researchers say more work is needed to confirm their hypothesis. If it is true, the hunt may be on for the companion the Sun once had. By: John Wenz

Kepler yields a handful of promising planetary candidates 19 June: The newest Kepler catalogue draws out 219 new planetary candidates and infers that 10 of them may be habitable — doubling the number of planetary candidates in the habitable zone of their star. The Kepler catalogue now stands at 2,335 confirmed planets and 4,034 strong candidates.

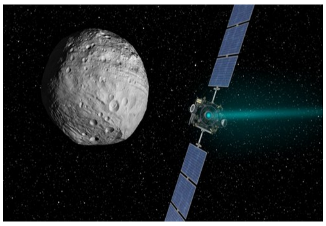
 NASA/JPL-Caltech/Wendy Stenzel

This catalogue marks the final results of the first Kepler mission, which stared at the same portion of the sky for three-and-a-half years before a busted reaction wheel forced NASA to pivot the mission to other forms of planet hunting. There were only a small number of newly confirmed planets.

The data of the final catalogue also suggests that there is a certain point at which super-Earths become more Neptune like, with a jump in mass as planets accumulate. This is why there seems to be so few planets between three and 10 Earth masses.

The Kepler telescope looked for planetary transits, when a planet passes in front of its star and causes a slight dip in its light. The original mission took a small sample of the sky in the Cygnus constellation to act as a sort of statistical survey. When a signal is sufficiently strong, it's considered confirmed. If it can't quite be confirmed, it's considered a candidate until further observation can verify a planet there. By: John Wenz

The fate of NASA's Dawn spacecraft is still undecided 20 June: NASA's Dawn spacecraft is low on hydrazine fuel and missing some wheels, but its fate after its current mission ends June 30 is still being decided.

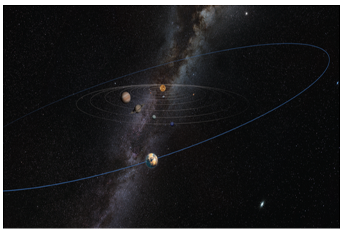

An artist's rendering of the Dawn spacecraft as it was arriving at asteroid Vesta back in July 2011. NASA/JPL-Caltech

The solar-powered spacecraft was launched back in September 2007 to study protoplanets in the asteroid belt, asteroid Vesta, and dwarf planet Ceres. Dawn arrived at Ceres in March 2015 and became the first spacecraft to visit a dwarf planet, beating New Horizons' visit to Pluto by just four months. While studying Ceres, Dawn found an ice-rich crust, evidence that pointed toward an underground ocean.

During this mission, Dawn ended up losing three of its four reaction wheels, which are used to control what the spacecraft points at. Carol Raymond, deputy principal investigator at NASA's Jet Propulsion Laboratory, told SpaceFlightNow that the loss of the third wheel was may not end the mission, but it does have an impact on the amount of time Dawn has left. With missing wheels and low fuel, the teams are weighing the financial costs of Dawn and the scientific payoff to decide what to do with Dawn come June 30. The options right now are to stay at Ceres, send Dawn off on another object, or just shut the craft down altogether.

Dawn uses more hydrazine to control the craft's orientation when it is closer to Ceres and when it is in lower orbits, so sending it off on another mission may preserve fuel, but the final decision will be up to NASA. By: Nicole Kiefert

Is there another Planet Nine altogether? 22 June: An Earth or Mars-sized world, or even two, may exist on the outskirts of the Kuiper Belt at an eight degree inclined orbit, shifting a number of Kuiper Belt orbits up to a similar inclination.


Heather Roper/LPL

The planet-mass object would be about 60 AU from the Sun. One AU is the distance between the Sun and Earth, with Pluto at about 30 AU at closest approach. The proposed planet, hypothesised by Kat Volk and Renu Malhotra of the University of Arizona, is different than the one proposed by Caltech's Mike Brown and Konstantin Batygin. Brown and Batygin propose a much more distant ice giant a bit smaller than Neptune, whereas Volk and Malhorta's planet is smaller and much closer in.

In fact, one does not preclude the existence of the other as the dwarf planets affected by Planet Nine's orbit far, far away. If it clears its orbit to meet the definition of a planet (and actually exists) we could probably consider it Planet Nine and rename Planet Nine to

Planet Ten. Or if you're a Pluto Truther, consider it Planet Ten, Eris as Planet Eleven (same size as Pluto so you have to count it), and Planet Nine as Planet Twelve. Regardless, we could have a long lost sister to Earth and Mars lurking surprisingly close, in overall solar system terms. By: John Wenz

Astronomers spot a pair of orbiting supermassive black holes 29 June:
Supermassive black holes are the monstrous objects found in the centrers of galaxies. The Milky Way's own supermassive black hole weighs nearly 4 million times more than our Sun. Although massive and often active, these objects are still difficult to 'see' in the traditional sense of the word for many reasons. Now, using the uniquely sharp 'vision' afforded by the National Science Foundation's Very Long Baseline Array (VLBA), astronomers have spotted for the first time a pair of supermassive black holes orbiting each other in a galaxy 750 million light-years away.


This artist's concept shows what the center of the elliptical galaxy 0402+379, as two supermassive black holes orbit each other with just 24 light-years between them. Josh Valenzuela/University of New Mexico

The discovery utilised radio information to determine that the two supermassive black holes are a mere 24 light-years apart and have a combined mass of about 15 billion times the mass of our Sun. It takes them about 30,000 years to complete a single orbit. The pair of supermassive black holes is located in a giant elliptical galaxy called 0402+379, which was first observed to have two "core" regions in data taken in 2003 and 2005 with the VLBA. The VLBA is part of the Long Baseline Observatory, a radio telescope system utilizing 10 antennas located between Hawaii's Big Island and St. Croix. Such a long baseline, or large distance between the dishes, allows astronomers to combine the data taken from each to observe objects with significantly greater detail than using one dish alone.

New observations of 0402+379 were taken in 2009 and 2015; when this information was combined with the previous observations, astronomers was finally able to identify the motion of two distinct supermassive black holes. "This is the first pair of black holes to be seen as separate objects that are moving with respect to each other, and thus makes this the first black-hole 'visual binary,'" said Greg Taylor of the University of New Mexico, one of the studys authors.

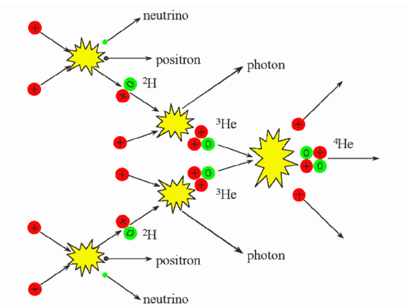
Why does this galaxy have two supermassive black holes? The presence of two such objects simply indicates that the galaxy has undergone a merger in the relatively recent cosmic past. When two galaxies combine, each contributes a supermassive black hole to the final product; in time, these two supermassive black holes should also combine, leaving behind a single object. In the case of 0402+379, this just has not happened yet, and likely will not happen for a few million years yet. That is how long it will take for the orbits of the supermassive black holes to spiral inward via the loss of energy through gravitational radiation, such as the gravitational waves detected by the Laser Interferometer Gravitational-Wave Observatory (LIGO).

Such pairs of supermassive black holes should actually be quite common, given the fact that galaxy mergers are themselves common events. Mergers are how galaxies grow over cosmic time, morphing from young, active spiral galaxies into old, quiescent ellipticals. “Now that we've been able to measure orbital motion in one such pair, we're encouraged to seek other, similar pairs. We may find others that are easier to study,” explained Karishma Bansal, a graduate student at the University of New Mexico and lead author of the study. Howeever, the confirmation of a pair of supermassive black holes in 0402+379 is not the end of astronomers’ interest in this galaxy. “We need to continue observing this galaxy to improve our understanding of the orbit, and of the masses of the black holes,” stressed Taylor. “This pair of black holes offers us our first chance to study how such systems interact.” By: Alison Klesman

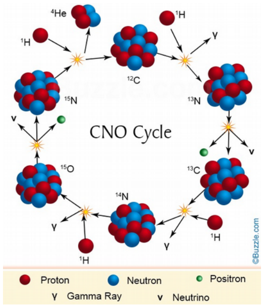
Source of these and further astronomy news items: www.astronomy.com/news

DID YOU KNOW?

The Sun Part 16: **Sun- energy production 3**



Proton-proton chain reaction



Carbon-nitrogen-oxygen (CNO) reaction

The carbon-nitrogen-oxygen (CNO) cycle dominates in higher mass stars and in the later life of smaller stars like the Sun as their core temperature rises. It is a 6- stage catalytic cycle that uses the nuclei of carbon, nitrogen, and oxygen as intermediaries to produce a helium nucleus. Unit energy production is slightly lower than that of the proton-proton (p-p) chain reaction, this difference in energy being accounted for by energy lost through neutrino emission.

The CNO cycle is very sensitive to temperature, so is strongly concentrated at the core. About 90% of the cycle’s energy generation occurs within inner 15% of the stars mass. This results in an intense outward energy flux that cannot be sustained by radiative transfer, as is the case in the p-p chain. As a result, the core becomes a convective zone which stirs the hydrogen burning regions, keeping it well mixed with the surrounding proton-rich region. This core convection occurs in stars when CNO cycle contributes more than 20% of the total energy. As the star ages and the core temperature increases, the region occupied by convection zone slowly shrinks from 20% of mass down to the inner 8% of mass.

The type of hydrogen burning that dominates inside a star is determined by temperature dependency differences between the two reactions. The p-p chain reaction starts at temperatures around 14 million K, making it the dominant mechanism in smaller stars, like the Sun. A self-maintaining CNO cycle requires a higher temperature of approximately 15 million K, but, thereafter, it increases more rapidly in efficiency than the p-p chain as the temperature increases. Above approx 17 million K, the CNO cycle becomes the dominant source of energy. This temperature is achieved in cores of main-sequence stars with at least 1.3 times the Sun's mass.

The Sun has a core temperature of around 15 million K and only 0.8% of energy produced in it is from CNO cycle. As a main-sequence star, like the Sun, ages, its core temperature rises, resulting in steadily increasing contribution from its CNO cycle.

Once a star with about 0.5-10 times the Sun's mass has consumed nearly all the hydrogen at its core, it begins to experience helium burning and evolve up the red giant branch of its life cycle. Helium burning occurs in a shell surrounding an inert helium core until the steadily increasing core temp exceeds a billion K. At this point, helium burning begins with a thermal runaway process, the helium flash, with hydrogen burning continuing in a thin shell surrounding the now active helium core.

Once the Sun reaches the red giant stage is will be producing energy via the triple-alpha process whereby three helium nuclei are fused to form carbon. It is also known as the Salpeter process, for the American astrophysicist Edwin Salpeter. This process requires temperatures of at least 100 million K. It operates in stars only larger than about 0.4 solar masses and only when all the hydrogen has been converted into helium.

Carbon creation is important because its formation form helium is a bottleneck in the entire process. It is produced by the triple-alpha process in all stars. Its formation is the key to production of heavier elements in stars. In very large stars, it is the main element causing release of free neutrons which, give rise to the s-process in which the slow absorption of neutrons converts iron into elements heaver than iron or nickel. In lower mas stars, like the Sun, nucleosynthesis is able to produce elements up to and including iron and nickel, but not any heavier elements.

The products of stellar nucleosynthesis are generally dispersed into the interstellar gas through mass loss episodes and the stellar winds of low mass stars. Stars lose most of their mass when it is ejected later in their stellar lifetimes. Mass loss events occur in the planetary nebula phase of low-mass star evolution like that of the Sun, and the explosive ending of stars more than eight solar masses as supernovas. These processes increase the abundance of elements heavier than in the interstellar medium

Sources: Ridpath, I (Ed) (2012) Oxford dictionary of astronomy 2nd ed rev, Singh, S (2004) Big Bang, www.en.wikipedia.org

For more information on the Hermanus Astronomy Centre and its activities, visit our website at www.hermanusastronomy.co.za

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