"The Southern Cross"

HERMANUS ASTRONOMY CENTRE NEWSLETTER

JANUARY 2017

As the Centre enters its tenth year, we wish all our members a very happy New Year and all the best for 2017.

Stargazing The next event is scheduled for **Friday 6 January 2017** at **Lemm's Corner** (Cnr. Main and Harbour Rds) from **19.00.** Weather permitting, both the Moon and, later, stars will be observed through binoculars and telescopes as well as naked eye.

This month's Centre meeting
This take place on **Monday 23 January** at the **Scout Hall** starting at **19.00**. Dr Bradley Frank, from UCT's Astrophysics, Cosmology and Gravity Centre, will be presenting 'SKA – a crash course'. Further details are given in 'This month's activities'.

Membership renewal for 2017
The fees for 2017 are are as follows:

Member: R150
Member's spouse/partner/child, student: R75

Six-month membership from July – December 2017:
Member: R75 Member's spouse etc, student: R40

Payment can be made in cash (at meetings directly to the Treasurer), or via online transfer. The Standard Bank details, for the latter, are as follows:

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

If you make an online donation, please reference your name and 'subs' or 'membership', or it is not possible to attribute the payment to you.

WHAT'S UP?

Two red summer stars The reddish colours of Betelgeuse (Alpha Orionis) at the right shoulder of the upside-down hunter Orion and Aldebaran (Alpha Tauri), at the right base of the inverted V of the Hyades cluster in neighbouring Taurus, are easy to identify with the naked eye. Interestingly, both are much closer than the other stars in their groupings: Aldebaran around 67 ly and Betelgeuse around 500 ly. Their colour illustrates that they are both in the later stages of their lives. Their hydrogen supplies have been depleted and they are burning helium as they slowly run out of fuel. Despite these similarities, their ends will differ widely. The massive supergiant Betelgeuse will die in a huge supernova explosion, events which can be over a billion time brighter than the Sun. In contrast, the smaller red giant Aldebaran will, like other stars around the size of the Sun, more sedately shed its outer layers as a planetary nebula while its core will survive quietly for millions of years as a white dwarf.

LAST MONTH'S ACTIVITIES

Monthly centre meeting The members and partners who attended the annual Christmas party on 12 December enjoyed a wonderful evening of food, entertainment ad convivial company. Jenny Morris reports: 'The evening started with an enjoyable presentation of some of the activities which the Centre undertook within the local community during 2016. It was a valuable reminder of how much happened during the year in addition to the scheduled monthly and interest group meetings. This was followed by a mouthwatering meal of tasty delights, many enjoying seconds! Then, before desert was served, four teams competed to win the famous quiz. There was much inspired answering as well as head-scratching and muttering. In the end, however, the score didn't matter. It was the taking part that counted. Many thanks to Karin de Bruin, Susan Joubert and their assistants for a wonderful evening."

Interest groups

Cosmology Sixteen people (15 members, 1 visitor) attended the meeting on 5 December. They considered the main points of the fourth of five short books on quantum mechanics by Dr Robert Piccioni of Stanford University. The topic of 'Spin, lasers, Pauli exclusion and barrier penetration' again encouraged thoughtful questions and lively discussion.

Astro-photography There was no meeting in December.

Other activities

Educational outreach
Hawston Secondary School Astronomy Group No meeting was held in December.
Lukhanyo Youth Club No meeting took place in December.

Whale Coast magazine An article by Jenny Morris titled 'Observing the Universe: size matters' was published in the December 2016-January 2017 issue of the magazine.

THIS MONTH'S ACTIVITIES

Monthly centre meeting The first meeting of 2017 will take place on **Monday 23 January** at the **Scout Hall** starting at **19.00**. The topic to be presented by Dr Bradley Frank, from the UCT Astrophysics, Cosmology and Gravity Centre, is 'SKA – a crash course'.

The Square Kilometre Array (SKA) will be the largest telescope ever built on Earth. It will be shared between South Africa and Australia; the majority of the dish array will be hosted in South Africa. There has been much progress in the past few years. The MeerKAT radio telescope in the Karoo (an SKA pathfinder), will be one of the most sensitive radio telescopes in the world, and will pave the way to the SKA with several ambitious and exciting science projects – many of which are being led by South African scientists. However, despite the publicity and public support that the project enjoys, the operations and science behind a radio telescope remains a mystery. How does a radio telescope convert voltages to images? Why do we need so many single dishes? Why is it spread over such large distances? Dr. Frank will provide a gentle introduction to the principles behind a radio telescope, he will also focus on the scientific questions that astronomers will address with MeerKAT and the SKA.

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. There is no meeting in January. The next meeting will take place on 6 February.

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 16 January. Members will continue work on processing their own 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

Stargazing The next event is scheduled for **Friday 6 January 2017.** Further details will be circulated in due course.

Hermanus Youth Robotic Telescope Interest Group Organisers continue to work towards accessing a telescope or images which learners can use in the coming year.

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

FUTURE ACTIVITIES

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

2016 MONTHLY MEETINGS

Unless stated otherwise, meetings take place on the **third Monday** of each month at the Scout Hall beginning at 19.00. Details for 2017 are:

23 Jan	'SKA: a crash course' Presenter: Dr Bradley Frank, UCT Astrophysics, Cosmology and Gravity Centre
20 Feb	AGM
20 Mar	'What science we have learned from space telscopes' Presenter: Pierre de Villiers, Committee chariperson
17 April	'Colliding black holes' Presenter: Bishop Mongwane, Doctoral student, UCT Astrophysics, Cosmology and Gravity Centre
15 May	'Asteroids, comets and dwarf planets' Presenter: Johan Retief, Centre member
19 June	'The monsters of deep space' Presenter David Groenewald, SAAO, CT
17 July	'Deep sky stargazing' Presenter: Auke Slotegraaf, psychohisotiran and editor of the Sky Guide

21 Aug	TBA
18 Sept	TBA
16 Oct	'Jupiter: the neighbourhood bully' Presenter: Jenny Morris, Committee member
20 Nov	TBA
11 Dec	Xmas party

ASTRONOMY EDUCATION CENTRE AND AMPHITHEATRE (AECA)

Hopefully, the planning application will be considered by the Council of Overstrand Municipality at their February meeting. 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:

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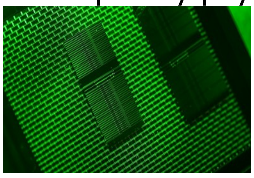
ASTRONOMY NEWS

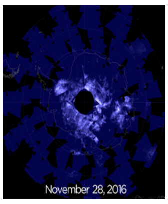
A new instrument could give a clear view of distant exoplanets 6 December: A star's brightness often drowns out a view of its planetary system, but the new optical chip developed by physicists and astronomers in Australia


The new telescope chip from ANU Stuart Hay, ANU

This chip is designed for a telescope and gives astronomers a clear view of planets outside our solar system that may support life. Associate Professor Steve Madden from The Australian National University said, in a press release, that this chip removes the light from the host star, which leaves a clear image of the planet for astronomers. Madden compares the light cancelling chip to how noise cancelling headphones work. "This chip is an interferometer that adds equal but opposite light waves from a host sun, which cancels out the light from the sun, allowing the much weaker planet to be seen," Madden said. "The chip allows the heat emitted from the planet to peer through dust clouds and see planets forming," PhD student Harry Dean Kenchington Goldsmith from the ANU Research

School of Physics and Engineering said. "Ultimately the same technology will allow us to detect ozone on alien planets that could support life." By: Nicole Kiefert

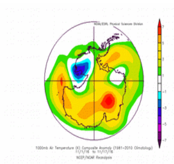
Electric-blue ice clouds seeded by meteor dust have been spied over Antarctica by a NASA spacecraft 6 December: As summer gets under way in the Southern Hemisphere, electric blue clouds seeded by meteor dust begin to glow high in the sky over Antarctica's vast icy reaches. This year, according to NASA, these night-shining, or 'noctilucent', clouds turned up much earlier than usual. This corresponds to an early seasonal shift into into the warmer season at lower altitudes over Antarctica.



An animation based on data from NASA's AIM spacecraft shows the sky over Antarctica glowing blue at the start of noctilucent cloud season in the Southern Hemisphere. The data were acquired by AIM Nov. 17 to 28, 2016. NASA/HU/VT/CU-LASP/AIM/Joy Ng, producer

Noctilucent clouds are Earth's highest clouds, sandwiched between Earth and space 80 km above the ground in a layer of the atmosphere called the mesosphere. Seeded by fine debris from disintegrating meteors, these clouds of ice crystals glow a bright, shocking blue when they reflect sunlight. If you are wondering how sunlight can illuminate clouds at night, consider that the midnight Sun has been present over most of Antarctica during much of November. In the animation above of AIM spacecraft data gathered over Antarctica — which shows noctilucent clouds evolving in the second half of the month — watch for the expanding dotted circle. This marks the edge of the region experiencing the midnight sun.

The onset of night-shining clouds over Antarctica was witnessed by NASA's Aeronomy of Ice in the Mesosphere spacecraft starting on 17 November. That puts this year in a tie for the earliest start yet in the AIM record of the Southern Hemisphere. In the Southern Hemisphere, AIM has observed seasons beginning anywhere from 17 November to 16 December. According to NASA, noctilucent clouds are observed seasonally, during summer in both the Northern and Southern hemispheres. This is when the mesosphere is most humid, with water vapour wafting up from lower altitudes. Additionally, this is also when the mesosphere is the coldest place on Earth – dropping as low as minus 210 degrees Fahrenheit – due to seasonal air flow patterns.


Air temperature anomalies at roughly 300 feet above the surface in Antarctica during the first half of November, as determined by both modelling and observations. NOAA Earth System Research Laboratory

The mesosphere is also exceedingly dry. In fact, it is 100 million times drier than air over the Sahara desert. Yet noctilucent clouds are made of water — tiny water ice crystals about the size of particles in cigarette smoke. So where does the water for these crystals come from, and how do they form? The warming of the relatively moist lower atmosphere that occurs during summer causes upwelling winds. These carry water vapour high into the mesosphere. This is why the clouds appear during summer, not winter. However, that by itself would not cause ice crystals to grow and collect into noctilucent clouds. The water molecules need something to stick to in order to form crystals. In ordinary clouds lower in the atmosphere, dust whipped up by winds often serve the purpose, but the mesosphere is so high that another source of dust is needed. That is where meteor dust comes in. Many tons of tiny flecks of smashed up comets and asteroids enter the mesosphere every day. And as it turns out, much of this stuff is just the right size to seed the formation of the ice crystals that comprise noctilucent clouds.

Global warming may be helping the clouds spread by making the already frigid mesosphere even colder. That may sound like a contradiction, since greenhouse gases cause warming, but this is so in the lower reaches of Earth's atmosphere. In the mesosphere, greenhouse gases actually serve to lower temperatures. Did an earlier-than-normal shift to summer conditions in the lower atmosphere over Antarctica contribute to the early start of noctilucent cloud season there? The lower atmosphere over Antarctica was, in fact, warmer than normal in the weeks leading up to the onset of the noctilucent clouds, as the graphic above shows. It is possible that this enhanced the transport of water vapour up into the mesosphere, thus providing the raw materials needed for forming the clouds. That is an intriguing hypothesis. However, it is also important to keep in mind that the AIM mission has only been underway since 2007. So scientists do not have a long satellite record showing the onset and evolution of the noctilucent cloud season over Antarctica. By: Tom Yulsman

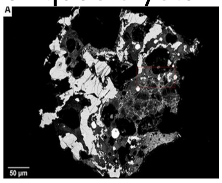
Oh great, so Alpha Centauri is not Alpha Centauri anymore 7 December: The International Astronomical Union (IAU) may have supervillain status among some sky enthusiasts for its decision to demote Pluto from planet to dwarf planet 10 years ago. Now, they are going to divide the astronomy community again. Goodbye, Alpha Centauri. Hello, Rigil Kentaurus.


Skatebiker / ESO

The decision was announced on 24 November. The IAU gave official designations to 227 stars, making Vega officially Vega, Mizar officially Mizar, Aldebaran officially Aldebaran, and Alpha Centauri its ancient name. Potentially adding to the confusion, a faint companion to the two stars comprising the now Rigil Kentaurus system, known as Proxima Centauri, has been officially designated by that name. This means the stars are Rigil Kentaurus A and B and Proxima Centauri.

Too many old school astronomers (amateur and institutional) think the change may not be so hard to swallow. Arabic astronomers called the star system Rijl Qanṭūris, which roughly translates to 'the foot of the centaur'. Rigil Kentaurus would be a rendering of that name. It was eventually given a Bayer designation of α Centauri, and other stars in the Centaurus nebula given other Greek letters. The names have been used interchangeably, with some observers preferring the Arabic transliteration. In the end, the amount it matters is nil. People can continue to call it Alpha Centauri, but some star charts may change to reflect the IAU designation. References might get a little tricky without a parenthetical of (aka Alpha Centauri.) By: John Wenz

An old meteor yields a new surprise: a never-before-seen material 8 December: It is not every day scientists discover an entirely new material adrift in the universe, but in pouring over the Khatyrka meteorite, researchers led by Luca Bindi found an all-new type of quasicrystal never seen before.


Quasicrystals provide a new perspective on solids Luca Bindi, Chaney Lin, Chi Ma & Paul J. Steinhardt

Quasicrystals are an odd geological material residing somewhere between the tidy order of classic crystals like quartz and diamonds, and the utter chaos of amorphous messes like obsidian and glass. Crystalline solids have a regular chemical composition building a repeating pattern with very clearly-defined symmetry. Amorphous solids have no pattern or symmetry at all. Quasiperiod crystals – quasicrystals for short – have patterns without repeating. The result is more akin to medieval Islamic mosaics than kitchen tiles, patterns following mathematics rules without the symmetry fundamental to crystals.

Quasicrystals have a dramatic history. Dan Shechtman grew the first quasicrystal in 1982, a discovery so controversial he was asked to leave his research lab. However, the evidence was overwhelming: this was a new type of material. Schechtman was honoured for the discovery with the 2011 Nobel Prize in Chemistry. More synthetic crystals followed, but the next breakthrough was finding two matching quasicrystals in tiny fragments of the Khatyrka meteorite in 2009. The first wild quasicrystals' structures were familiar, a variation on a synthetic quasicrystal grown from aluminium, copper, and iron in the lab. Today's discovery of a new quasicrystal from the same meteorite is even more exciting, marking not just the third quasicrystal ever found in nature, but also the first new type of quasicrystal found the wild before it was ever grown in a lab.

In the laboratory, quasicrystals need very particular conditions for growth or the same mix of chemicals will default into a symmetrical crystal structure instead. So how do they form in the chaotic real world? A research group led by Paul Asimow and including Bindi tried to experimentally recreate scenarios that could spawn quasicrystals. Taking a hint from Khatyrka's evident history of violent collisions leading to shock-melting at over 5GPa of pressure at 1,200 °C, they fired bullets of mock-meteorites into a larger stationary fragment in a high-energy dead-on impact. The results announced earlier this year proved that, at least in theory, asteroids ramming into each other with enough energy followed by the rapid cooling enabled by deep space creates, briefly, an environment where quasicrystals naturally spawn. Encouraged, Bindi, Shechtman, and the rest of the team started reanalysing their precious rock, searching for any more evidence to support their theories. They methodically searched for quasicrystals just a few microns in size, the proverbial needle in the haystack but harder to find. Their painstaking search paid off: on a meteorite chip less than half a millimetre across, they found their needle, an new quasicrystal. Like the previous discovery, it formed from a mix of aluminium, copper, and iron, but in different proportions to create an all-new structure never seen before.

By: Mika McKinnon

Stony meteorites reveal the timing of Jupiter's migration 13 December: The gas giant caused iron-vaporising collisions in the asteroid belt 5 billion years ago. The youngest stony meteorites in the solar system may reveal when Jupiter migrated through the asteroid belt. These meteors contain grains of metal that can only be the remnant of high-velocity collisions driven by Jupiter's gravitational influence.

An artist's rendering of Jupiter WikiMedia Commons/ Ukstillalive

New evidence comes from a rare group of meteorites called CB chondrites. Formed around 4.8 to 5 billion years ago, they are the product of objects slamming into each other at very high speeds in the wild early days of the solar system. CB chondrites contain grains of iron and nickel whose structure means they must have condensed directly from a vapour to solid form. Those tiny irregular grains of condensed metal were once part of the iron-nickel cores of rocky objects in the early solar system, and their presence points to a series of high-speed collisions between those objects, with enough shock and heat to vaporise iron.

Our solar system did not always look like it does now. The gas giants might have begun their lives much closer to the Sun and then migrated outward, or they maighthave made only a brief venture inward before retreating again. The evidence of the gas giants' migration is etched in the solar system they left behind – the composition and dynamics of the rocky objects of the inner solar system. "Much of the structure of our solar system is driven by the formation and migration of the giant planets," said Brandon Johnson, a planetary scientist at Brown University who studies impact dynamics.

Vaporising iron is not an easy task. To shock vaporise the iron core of a rocky asteroid requires an impact at around 18 km per second, according to laboratory experiments and computer modelling. At that speed, the shock wave of impact compresses and heats the asteroids metal core and silicate mantle, turning it into a supercritical fluid - material under so much heat and pressure that there's no longer a difference between its liquid and gas phases. Once the shock wave passes, the pressure lets up and the fluid becomes a mix of liquid and vapour. As it cools, the vapour condenses onto drops of molten metal and silicates, forming the metal grains seen in CB chondrites today.

The trouble is that the standard model of how the solar system formed does not get objects in the asteroid belt moving at speeds great enough to produce those metal-vaporizing impacts. That requires something big to stir things up – like a gravitational boost from a wandering gas giant. With its tremendous gravity, Jupiter would have been able to slingshot objects at speeds more than sufficient to vaporize iron on impact. Jupiter's gravitational pull would also have pulled in material from the outer reaches of the solar system, mixing it with what was already in the asteroid belt. That accounts for the diversity of material seen in the modern asteroid belt, not to mention the presence of material from the outer solar system in today's CB chondrites.

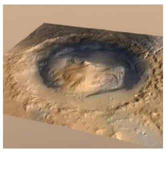
Scientists already generally accept the idea that Jupiter and the other gas giants did not form in their current positions, but instead migrated into their present orbits earlier in the solar system's history. Most of the debate now centres on when they migrated and what course they followed. Realising that CB chondrites require Jupiter's interference to form, and knowing when they formed, helps narrow down the timing. One of the most popular models for Jupiter's migration, called the Grand Tack, has the gas giant forming in an orbit about 3.5 astronomical units, or AU, from the Sun (1 AU is the distance between Earth and the Sun). As it gobbled up surrounding gas to build its thick atmosphere, Jupiter changed the distribution of material in the solar nebula, which eventually drew the planet inward toward the Sun. It made it to the vicinity of the present-day asteroid belt, and when Saturn formed, its gravitational influence nudged both gas giants outward again, so Jupiter ended up in its present-day orbit at 5.2 AU.

Johnson and his colleagues put the Grand Tack in their model of the early solar system. It turned out that for about half a million years, Jupiter's massive gravitational influence caused a major spike in impact velocities in the area that is now the asteroid belt. The model produced several smashing collisions, including one 33 km per second impact between a huge 300 km-wide object and a smaller 90 km one. That impact, according to the researchers, would have vaporized 30% to 60% of the larger object's metal core, producing the metal grains in CB chondrites.

Since scientists know, thanks to isotope testing, when the CB chondrites formed, this model helps them narrow down when Jupiter must have been passing through the inner solar system. Scientists generally agree on about how long it takes for a gas giant to form its planetary core, accrete most of the nearby gas, and start migrating. They also generally agree that migration stops once all the gas in the planetary nebula has been gobbled up, within about 100,000 to one million years after the gas giants start migrating. Putting all those pieces together means that the gas giants' planetary cores took about 4.5 to 5 million years to form, and that the solar nebula dispersed shortly afterwards. That is all from working backwards from the presence of weird grains of metal in a rare subtype of asteroid. "Our work demonstrates that meteorites may also offer clues about the young giant planets and their wanderlust," said Johnson.

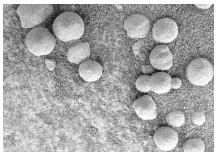
However, narrowing down the timing does not answer all of the potential questions about Jupiter's long-ago wandering. The Grand Tack is not the only plausible model for the gas giant's path; other models have Jupiter starting in the inner solar system, much closer to the Sun, and slowly moving outward. Johnson's modelling does not narrow down exactly which path Jupiter took, but it does make it pretty clear that the gas giant had to be in the neighbourhood within a pretty narrow window in order to account for the presence of CB chondrites. The evidence supports any scenario that puts Jupiter in the right place at the right time. "I think that models that explore a range of potential migration pathways will narrow down what most likely happened in our system. This is something that we are pursuing as future work," he said. By: K N Smith

Soupy mix of minerals a 'jackpot' on Mars 14 December: Today, the Red Planet is a dry, dusty landscape devoid of hospitable environments, but the Mars of yesteryear, evidence suggests, was a far more forgiving place. Recently, Curiosity discovered something on the Red Planet that has never been seen before: boron. This finding is of particular interest to scientists because boron is usually found in abundance of groundwater, and where we find water we tend to find life. NASA's mission, after all, is to always 'follow the water'.


Mount Sharp rises inside Gale Crater. NASA/JPL/ESA/DLR/FU Berlin/MSSS

It has been known for some time that Gale Crater, the site of Curiosity's mission, was once home to a large lake, but there have been questions as to what Curiosity would find as it ascended Mount Sharp, which rises in the middle of the crater. Though the team suspected they might find boron on Mars, they were surprised to find it where they did. Boron is usually found in arid climates, where water has long since evaporated, leaving behind a dry arid lakebed. An Earth-type analogue for this would be Death Valley in California, where years ago boron was hauled out en masse to be used as detergent - Borax - due to its dissolvability in water.

Scientists think boron may have been deposited on Mars after water in Gale Lake evaporated, or could have been transferred into the rock layer from groundwater above. In the same location, Curiosity also found the mineral haematite, which we've seen before on Mars from the Opportunity rover in the form of 'berries'.


A microscopic image snapped by Opportunity near an outcrop called the 'Berry Bowl', near the rover's landing site. NASA

Haematite is iron-rich and is associated with warmer climates, but the discovery of these two at the same geological location could mean something really interesting was happening a few billion years ago. "Variations in these minerals and elements indicate a dynamic system. They interact with groundwater as well as surface water," says Grotzinger. Professor of geology at the California Institute of Technology, "The water influences the chemistry of the clays, but the composition of the water also changes. The more complicated the chemistry is, the better it is for habitability."

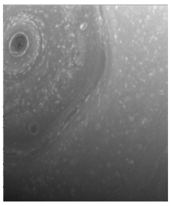
It is known that Mars could have once hosted life; after all, the planet still has frozen water on its surface. So how is this finding any more special than the others we've heard from Mars? "When we were at Yellowknife bay we accomplished 99 percent of what we set out to do, but what's changed is that as we've traversed the surface we've consistently seen these habitable conditions over time and in different locations across Mars," says Ashwin Vasavada, project scientist for the Mars Science Laboratory. "This isn't just in one location, but the last four years we keep coming up with evidence of habitability, and this new complex chemistry really points us to something." After four years in operation, Curiosity continues to provide glimpses of what Mars once looked like. While there's still no evidence of past life, there are locations throughout Mars that are prime candidates for investigations. Finding the right mineral combinations also indicates that water in Gale Crater might have been drinkable, not too salty, and not too acidic. By: Shannon Stirone

Cassini dives through Saturn's rings 16 December: Zipping along at 75,000 km an hour, the Cassini spacecraft made its first dive through the rings of Saturn on 11 December as part of the 'ring-grazing' phase of its mission. The little spacecraft will spend the next 20 weeks studying the most spectacular sight in our solar system, with special focus on the F ring. Cassini entered its ring-grazing orbit on 30 November at the farthest point in the orbit. Its nearest approach to Saturn is about 8,000 km outside the F ring. To enter its ring-grazing orbit, Cassini got a gravitational boost from the moon Titan, a manoeuvre Cassini has employed many times since its arrival at the Saturn system in 2004. In fact, Titan has been instrumental in shaping and prolonging Cassini's mission.

"Titan is quite large, and so every time we fly by, it bends our trajectory," says Earl Maize, Cassini project manager for NASA's Jet Propulsion Laboratory in Pasadena, California. The moon gives a boost of 500-700 meters per second to the little spacecraft, comparable to the main engine burn used to insert Cassini into Saturn's orbit. "So we've essentially had 125 massive main engine burns, and we've used that to tour around. We couldn't possibly have carried enough fuel to do what we've done with the gravity assist we get from Titan."

Cassini was low on fuel even before changing trajectory from its orbit well outside the rings into the current ring-grazing orbit. The main engine fired for what was probably the last time to make a course correction shortly before entering the ring-grazing orbit early on Sunday morning, Pasadena time. Cassini hit its mark within about 150 metres, says Maize. Instructions for the engine burn had to be transmitted well in advance to compensate for the one-and-a-half-hour travel time between Earth and Saturn, since the two planets are nearly on opposite sides of the Sun.

From its orbit close to the F ring, Cassini will be able to obtain unprecedented views of the complicated behaviour within the F, A, and B rings. The F ring alone presents plenty to watch. The thin, outermost discrete ring of Saturn orbits about 140,000 kilometres from the planet's centre and features spiral strands and channels. The ring particles are shepherded by two tiny moonlets, Prometheus inside the ring orbit and Pandora outside. When bodies within the F ring collide, they create dust that is ejected as streamers.



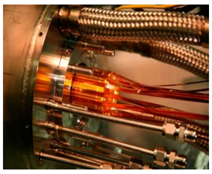
View from NASA's Cassini spacecraft obtained about half a day before its first close pass by the outer edges of Saturn's main rings during its penultimate mission phase. NASA/JPL-Caltech/Space Science Institute

Prometheus actually dives into the F ring periodically, when the outermost point of its eccentric orbit intersects with the innermost point in the ring's eccentric orbit. The two orbits precess around each other. The moonlet trails dark channels of disruption in its wake through the ring particles. "There's probably, we're hoping, enough particles that we can get a good sampling of the F ring particles or any gases coming off and directly measure their composition," says Linda Spilker, Cassini project scientist at the Jet Propulsion Laboratory.

Cassini will sample the dust particles outside the F ring using the Cosmic Dust Analyzer, which incorporates a mass spectrometer to determine the dust's composition. "We know that Saturn's rings in general are mostly made of water ice, probably 99 percent water ice," but the rings also show colours, Spilker says. "We're still not sure what that colouring is coming from. This is our first chance to perhaps get a closer look at some of those particles and see what they might be made of." Cassini will also get a good view of the 'propellers' in the outer part of the A ring, which is the next inside the F ring. Propellers are created by small objects that are not quite massive enough to clear a gap in the ring around them. "They, instead, have these two little arms, one in front and one behind, that are like partially opening up a gap," says Spilker. The propellers whimsically carry the nicknames of past aviators, such as Bleriot and Earhart. "Then there's this interesting feature at the outermost part of the A ring," she adds. "Turns out there's probably a large object forming in the outer part of the A ring. It got nicknamed Peggy."

Orbital resonances, when two orbiting bodies feel a periodic gravitational tug on each other, also cause some behaviour in the rings, such as gaps and spiral waves. The inner boundary of the Cassini Division, for example, between the A and B rings orbits twice for every orbit of the moon Mimas. The rings also display resonance behaviour caused by Saturn itself, according to Spilker. Cassini's orbits after the ring-grazing phase, known as the Grand Finale, will pull the spacecraft even closer to the planet. Beginning in April 2017, the close orbits, as close as 1,628 kilometres above Saturn's cloud tops, may reveal clues to what might cause the Saturn-induced resonances. The close orbits will also allow Cassini to measure the mass of the rings by subtracting the planet's mass from the combined mass of the planet-ring system. With the Grand Finale orbits between the planet and the rings, Cassini will also be able to measure Saturn's close gravitational and magnetic fields and gather clues about whatever structure might be hidden beneath Saturn's clouds. By: Allen Zeyher

CERN scientists get the first glance of the innards of antimatter 20 December: Antimatter is more than a science fiction concept that allows engineers to power the Enterprise. Its an actual, albeit small, constituent of the Universe. While antimatter is rare, it can exist under the right conditions. Information about the way antimatter behaves provides a powerful tool for testing the Standard Model of particle physics currently used to understand the forces that govern the way particles behave.


CERN

Antimatter was first predicted by British physicist Paul Dirac in 1928. He proposed that every particle of matter should have a corresponding antiparticle. These antiparticles are identical to their particle counterparts in every way except for charge. For example, the antimatter counterpart to the negatively-charged electron is the positively-charged anti-electron, also called the positron. When matter and antimatter meet, they annihilate each other and leave only energy behind. The Big Bang should have created matter and antimatter in equal amounts, but today, our universe is dominated by matter, with very little antimatter present. Understanding why this asymmetry exists would be a significant step towards understanding the origin and evolution of our universe. However, naturally-occurring antimatter is often immediately destroyed when it encounters the universe's abundant matter. Today, particle physicists can routinely create antimatter for study at the CERN Antiproton Decelerator facility, which has led to several new breakthroughs in the characterization of antimatter.

CERN's ALPHA collaboration has announced the very first measurement of a spectral line in an anti-hydrogen atom. This result, which was over 20 years in the making, was achieved using a laser to observe the 1S-2S transition in anti-hydrogen. To within experimental limits, the ALPHA collaboration's results show that this transition is identical in both hydrogen and anti-hydrogen atoms - a condition required by the Standard Model. If these transitions were different, it would essentially break our current understanding of physics. The 1S-2S transition is one of many that contribute to hydrogen's spectrum. A spectrum is created when electrons that have been excited by radiation 'fall' from a higher energy level inside an atom to a lower one. This process releases energy at precise wavelengths. Each element produces a unique spectrum, like a fingerprint. Astronomers often use spectra to determine an object's composition based on the light it produces.

To observe the 1S-2S transition in anti-hydrogen, the ALPHA collaboration first had to create anti-atoms and keep them stable - no easy task. ALPHA's recipe for anti-hydrogen consisted of mixing plasmas containing anti-protons and positrons together to produce anti-hydrogen atoms. The resulting anti-atoms were then magnetically trapped to hold them for experimentation. From an original batch of 90,000 anti-protons, researchers could create 25,000 anti-hydrogen atoms; of these, the ALPHA collaboration managed to trap and study an average of 14 anti-atoms per trial. By illuminating the anti-hydrogen atoms with a laser tuned to provide exactly the energy needed to achieve the proposed transition, researchers were then able to observe the resulting emission to look for deviations from the spectrum of normal hydrogen By: Alison Klesman

Pioneering physicist on dark matter Vera Rubin dies at age 88 27 December: After receiving a BA from Vassar College in 1954, Rubin attempted to enroll in Princeton despite bans on female PhD candidates in astronomy. Eventually she attended Cornell University, earning a masters degree, before completing her studies at Georgetown University. From there, Rubin and colleague Kent Ford watched the rotation of nearby galaxies, studying the curves as they moved. Eventually, discrepancies between predictions of angular momentum and the actual angular momentum seemed to confirm dark matter. Dark matter was the 'missing mass' of the universe necessary to explain how the universe expanded, so called because it was not accounted for by known stars, galaxies, and other objects. While it had been discussed as early as the 1920s (Jacobus Kapteyn was the first to suggest it) and Fritz Zwicky (who coined the term 'dark matter' while studying galactic motion in galaxy clusters in the 1930s), Rubin's work helped solidify the emerging field of dark matter research in the present day, confirming the work of Zwicky, Kapteyn, and others by nailing down precise measurements of the necessary amounts of dark matter to confirm galactic-scale observations. In essence, galaxies were moving faster than they should have been based on the estimated number of stars and other material in spiral galaxies, something that had to be accounted for by unseen forces.

While Rubin's work might have helped usher in the modern age of dark matter research, she was also a tireless advocate for other women in STEM fields, saying, "We all need permission to do science, but, for reasons that are deeply ingrained in history, this permission is more often given to men than to women." Rubin's work helped carve out a path for other women in astronomy and other science disciplines. While she won numerous awards for her work, calls for Rubin to win a Nobel Prize in Physics went unheeded. By: John Wenz

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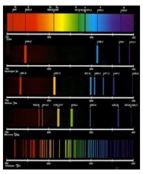
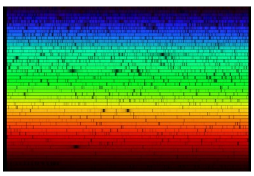
DID YOU KNOW?

The Sun Part 10: **Stellar spectral classification 1**



Sun's emission spectrum



Sun's absorption spectrum

The Sun is a G2V main-sequence star, or G dwarf star or, less accurately, yellow dwarf. It produces more yellow light than any other colour because of its surface temp of around 5.500 K. The hotter an object, the more the energy it radiates and the 'hotter' its colour. Thus, the colour of a star provides information about its temperature. These colours, and other characteristics, including luminosity (brightness), mass and distance can be identified from their spectra. This property, which has enabled scientists to classify stars according their spectral characteristics, has also provided valuable information on the nature and life cycle of stars.

Each line in a stellar spectrum indicates an ion of a certain chemical element. The line's strength indicates the abundance of that ion and the relative abundance of different ions varies with the temperature and density of its photosphere. Thus, the spectral class of a star, like the Sun, is a short code summarising its surface features.

Most stars are currently classified under the Morgan-Keenan (KN) or Yerkes system which was published in 1943. This two-dimensional system uses the letters O, B, A, F, G, K and M, a sequence from the hottest (O) to the coolest (M) type. These classes (and temperatures) relate to the optical colours of stars. The brightest (hottest) stars are white or blue-white, less hot ones yellow or orange, and cooler ones orange-red or red. Each letter is then subdivided with a numeric digit, with 0 being the hottest and 9 the coolest eg A8, A9, F0, F1 or G2 like the Sun. Fractional numbers are allowed eg 0.97. The sequence has been expanded with classes for other stars and star-like objects that do not fit the classical system eg D for white dwarfs, C for carbon stars.

The second dimension of the M-K system was the addition of a luminosity class. Using Roman numerals, it is based on the width of certain absorption lines in the star's spectrum which vary with density of the atmosphere, and so distinguish giant stars from dwarfs. In addition, stars have a luminosity class depending on their brightness. They are: class O or Ia+ for hypergiants, class Ia and Ib for supergiants, class II for bright giants, class III for regular gianst, class IV for sub-giants, class V for dwarfs (main-sequence stars eg Sun) class *sd* for sub-dwarfs and class D for white dwarfs. Thus, the Sun's full spectral classification of G2V identifies it as a yellow main-sequence star with a surface temperature around 5,000 K.

The M-K system is an advance on the earlier Harvard spectral classification, with more precise observational definition of each type and the addition of the numeric luminosity classification. The Harvard classification was also based on earlier systems. The reason for the odd letter arrangement in the Harvard system is historical, having evolved from earlier Secchi classes and being progressively modified as understanding improved. In 1866, Angelo Secchi, the pioneering Italian stellar spectroscopist created three classes in order to classify observed spectra. Class I included white and blue stars with broad, heavy hydrogen lines. This includes the modern class A and early class F types eg Vega, Altair. Class II contained yellow stars with less strong hydrogen, but more evident metallic lines eg Sun, Arcturus, Capella. This includes modern G and K as well as late class F types. Class III included orange to red stars with complex band spectra eg Betelgeuse, Antares. This corresponds to modern class M.

During the late 1890s, the Secchi system began to be superseded by what had became the Harvard classification. During the 1880s, the American astronomer Edward Pickering organised a survey of stellar spectra at Harvard Observatory using the objective prism method. The first product of this work was the 1890 Draper Catalogue of Stellar Spectra.

Most of the spectra in this catalogue were classified by Williamina Fleming, one of several pioneering female 'computers' employed by Pickering to undertake the demanding, but repetitive work of analysing spectra and photographs. The Draper catalogue used a scheme in which the existing Secchi classes were divided into more specific classes, given letters A to N . Also, the letters O, P, and Q were used to describe unusual stars and features.

The Harvard classification evolved from the Draper classification. Also a one-dimensional system based on temperature only, it similarly used single letters of the alphabet, but with changes in letter order, and the addition of with numeric sub-divisions to group stars according to their spectral characteristics, specifically the temperature of a star's surface. O, B and A stars are sometimes called 'early type' and K and M stars 'late type'. This stems from an early 20th century model of stellar evolution in which stars started their lives as very hot early types and then gradually cool down into late type. This mechanism was proved incorrect following discovery that stars are powered by nuclear fusion, but the labels lived on.

In 1897, another Harvard computer, Antonia Maury placed a sub-type of Secchi's Class I ahead of the remainder of Class I, thus placing modern type B ahead of A. She was first to do this, although she did not use lettered spectral types, rather a series of 22 types numbered from I to XXII. It was Annie Jump Cannon who, in 1901, returned to using Draper lettered types, but dropped all except letters O, B, A, F, G, K and M, used in that order. She also retained P for planetary nebulae and Q for some peculiar spectra
She also used labels like B5A for stars halfway between types B and A, F2G for stars 1/5 of the way from F to G etc. By 1912, she had changed types B, A, B5A, F2G etc to B0, A0, B5, F2 etc, thus essentially establishing the modern Harvard classification system.

Sources – Ridpath, I (Ed) (2012) Oxford dictionary of astronomy 2nd ed rev, www.en.wikipedia.org, www.missionscience.nasa.org

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