ADDITIONAL INFORMATION TO THE BOOKLET:

"YOUR GUIDE TO THE UNIVERSE"

Solar system updates

New Horizons is the space probe that was launched to a planet but got to a dwarf planet instead: When New Horizons was launched in January 2006, Pluto was still called a planet; when it finally reached Pluto in July 2015, Pluto's status had been changed to dwarf planet. New Horizons had its closest approach to Pluto on 14 July 2015 and then went on to fly further into the Kuiper Belt, passing by the Kuiper Belt object 486958 Arrokoth on 1 January 2019. New Horizons made the first detailed photos of Pluto. To see what this meant, have a look at images of Pluto over time on https://www.planetary.org/space-images/then-now-pluto.

Image of Pluto taken by New Horizons.

Also in the outer rages of the solar system, on 25 August 2012 the space probe Voyager 1 became the first man-made object to leave the solar system and enter the interstellar medium. It has since been joined by Voyager 2, which left the solar system on 5 November 2018. Amazingly, even after more than 40 years in space Voyager 1 and 2 still take measurements and broadcast them to Earth.

The Cassini-Huygens mission was brought to a spectacular end on 15 September 2017. After a series of close Saturn passings, approaching within the rings, the Cassini probe was deliberately crashed into Saturn's atmosphere. Destroying Cassini was important, as any chance of unintended contamination of Saturn's moons with life from Earth had to be avoided.

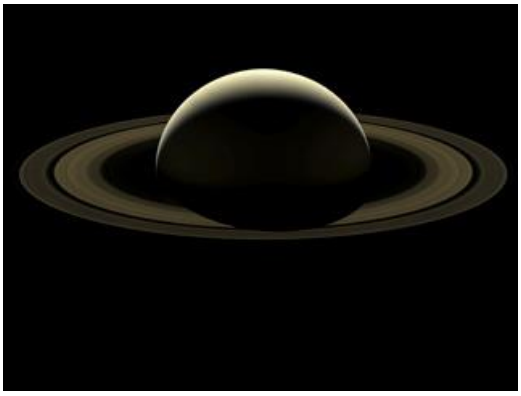
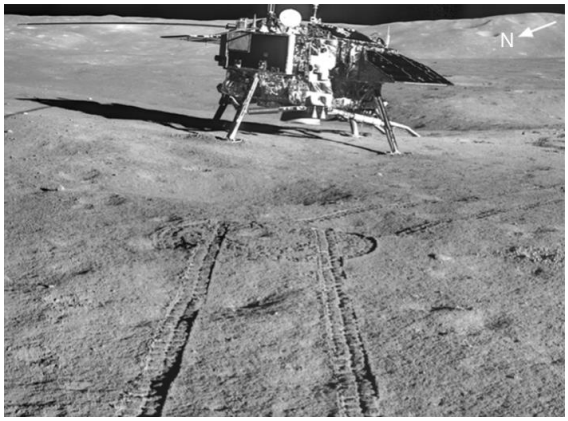


Image of Saturn and its rings taken by Cassini two days before it was crashed into Saturn's atmosphere.

On 27 June 2018 the Japanese space probe Hayabusa2 reached the asteroid 162173 Ryugu. It collected samples of the asteroid on 11 July 2019 and stored them in a sample return container. Hayabusa2 departed from the asteroid on 13 November 2019, heading back to Earth. When flying past Earth on 6 December 2020, it released the sample return container, which landed successfully in Australia.

China became the first nation to achieve a soft landing on the side of the Moon facing away from Earth. As part of its Chang'e 4 mission, the Yutu-2 rover landed on 3 January 2019 and started exploring the lunar surface. In December 2019 it became the longest working mission on the Moon. Don't think rovers are necessarily fast, though: By February 2021, Yutu-2 had travelled 629 meters.

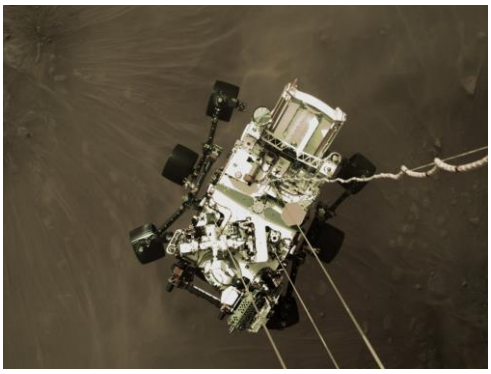


The Chang'e 4 lander photographed by the Yutu-2 rover.

The Parker Solar Probe was launched on 12 August 2018 to explore the lower solar corona. It has become the closest ever artificial object to the Sun, with its closest distance from the Sun's surface being 13.5 million kilometres (as of March 2021). The Parker Solar Probe cleverly uses Venus's gravity to slow down and get closer to the Sun. So far (March 2021) it has flown by Venus for four times, and it will have another three fly-bys, the last taking place in 2025. The probe has to withstand a lot of heat and radiation; on its closest encounters with Sun, the radiation will be more than 450 times that at Earth!

The latest rover to visit Mars is Perseverance, which landed on Mars on 18 February 2021. The landing was an amazing engineering feat; the rover had to be slowed down from 20 000 km per hour within seven minutes, and it had to decide on a safe landing spot on its own. Within minutes after landing the first pictures from Mars were sent back to Earth. During its mission Perseverance will search

for signs of (past) life and collect rock samples which might be returned to Earth in a decade or so. You can find out more at https://youtu.be/CqG0wG5UPWQ.

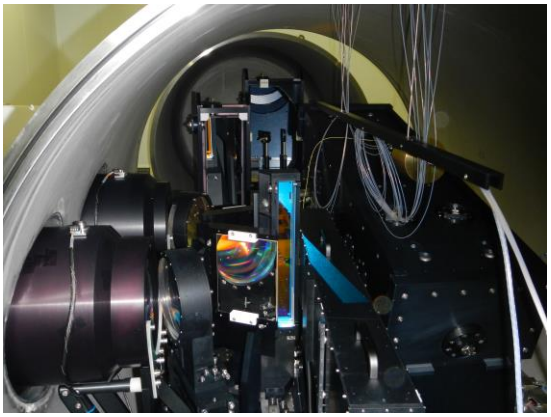


Perseverance landing on Mars.

During the conjunction of Jupiter and Saturn on 21 December 2020 the two planets were so close to each other that they (almost) appeared as a single bright dot to the naked eye. Their distance was 0.1 degrees, about one fifth of the Moon's diameter. They hadn't been that close to each other in the sky since 1623. However, bear in mind that Jupiter and Saturn only appeared so close to each other because they happened to be in almost the same direction as seen from Earth. Their actual distance from each other was still hundreds of millions of kilometres!

SALT updates

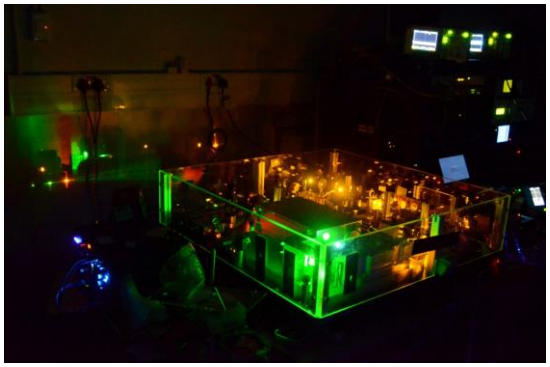
When SALT started observing, it had two instruments, the imaging camera Salticam and the Robert Stobie Spectrograph (RSS). Towards the end of 2013 they were joined by a new instrument, the High Resolution Spectrograph (HRS). Like RSS, HRS splits up the light into the different colours, but does it with a higher precision.



A look inside HRS.

There are various reasons why you might want to split up the light. An exciting one is the search for exoplanets (planets around other stars). Planets tug on their star, which leads to an ever-so-slight motion of the star. This in turn leads to a Doppler effect, meaning that sometimes the light is slightly redder and sometimes slightly bluer. This effect can be seen if you split up the light.

But the effect is tiny and you need special tools to know where on your image what wavelength (colour) is. One such tool is a laser frequency comb. This adds lines to your image. These lines are produced by a laser, and hence their wavelengths are very accurately known. Such a laser frequency comb was successfully tested on SALT in 2016.



A laser comb being tested at SALT.

A recent analysis has shown that HRS might be able to detect motions which are slower than a metre per second. This means that HRS could detect stars moving at the speed of pedestrians, even though they are trillions of kilometres away. For this reason it was decided to buy and install a laser frequency comb, supporting exoplanet science with SALT. It will probably become available in 2022.

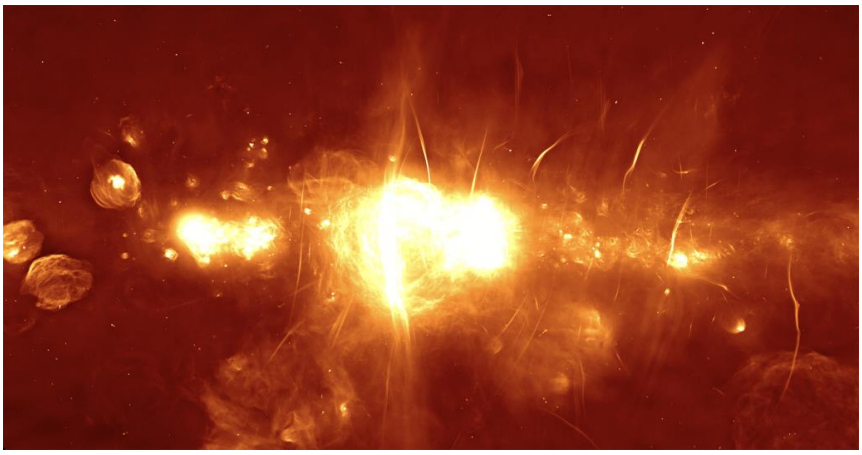
Also in 2022, a new instrument will arrive. The Near Infrared RSS (NIR) will extend RSS into the infrared and hence open up SALT to a new wavelength range, with new science opportunities.

SALT has a spherical mirror collecting light into a tracker with the instruments (and fibers leading to the instruments in the basement). But as the mirror is spherical, it would be possible to have additional trackers. Then you could observe several objects at the same time, greatly increasing SALT's efficiency. Such a Multi Target Tracking System is currently being designed.

MeerKAT updates

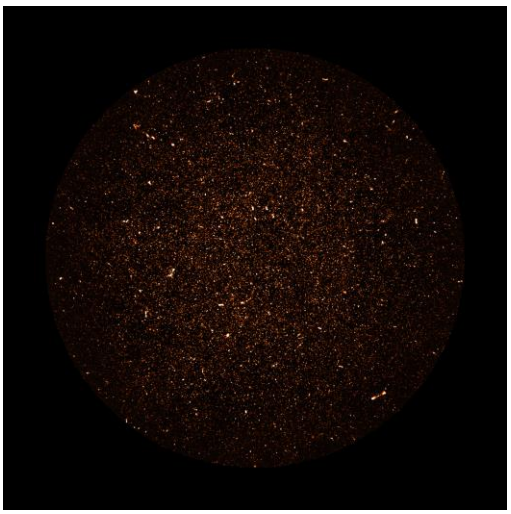
Work on MeerKAT progressed well, and all 64 dishes have been installed near Carnarvon in the Northern Cape. This means that South Africa now owns one of the best radio telescopes in the world.

When MeerKAT was officially inaugurated on 13 July 2018, a radio image of the centre of the Milky Way was released. Using data taken by MeerKAT, it showed details never seen before.



The centre of our Milky Way observed with MeerKAT.

The sensitivity of MeerKAT is also of great help when researching objects which are much further away than our Galaxy's centre. For example, MeerKAT observed an area the size of 5 full Moons for a total of 130 hours. The resulting image revealed thousands of



MeerKAT image of thousands of distant galaxies.

very distant Milky Way-like galaxies which had never been observed with a radio telescope before. This provided astronomers with new insights into star formation in the early Universe.

It often is extremely useful to combine results from optical and radio observations. So when in 2019 MeerKAT observed a radio source which rapidly brightened by three times over a period of three weeks, SALT and other telescopes in Sutherland were used to observe this object, providing valuable additional information.

The combination of optical and radio observations is so important that one of the telescopes in Sutherland is dedicated to it. MeerLICHT, which was inaugurated on 25 May 2018, simultaneously scans the sky together with MeerKAT, pointing in the same direction where MeerKAT is looking.

Building and running MeerKAT requires great expertise both in engineering and in project management, skills which are highly valuable outside astronomy as well. Hence the South African Radio Astronomy Observatory (SARAO) was in an excellent position to manage the national ventilator project, which produced 20 000 ventilators for Covid-19 patients in hospitals.

Updates for the SAAO steerable telescopes in Sutherland

Since 2013, a few telescopes have been added to the already large suite of local and hosted steerable telescopes at Sutherland. These include the new 1-m telescope called Lesedi and owned by the South African Astronomical Observatory (SAAO), KMTNet, MASTER, the LCO 0.4m telescope, MeerLICHT, the SANSA/DLR telescope, and Xamidimura (the two-telescope system that replaced SuperWASP, which was decommissioned in 2018). The future telescopes that are currently being built at Sutherland include ATLAS and PRIME.

Lesedi, the first fully South African owned telescope in Sutherland for 40 years, was inaugurated in 2017. The name Lesedi, a Sesotho word for light, was suggested by a grade 9 learner from the North-West Province, who also gave a speech and cut the ribbon at the inauguration ceremony at the telescope.

While the dome and mirror are the most obvious parts of a telescope, its instruments are at least as important. Expertise in building astronomical instruments has steadily increased in South Africa over the last years. For Lesedi, the South African Astronomical Observatory (SAAO) designed and built Sibonise (meaning „Show us“ in isiXhosa). This is an imaging camera, and it has the largest detector on any SAAO instrument - each image it takes covers an area 40 times larger than that covered by any other of the SAAO's cameras.

One of the (fortunately rather small) risks for life on Earth is being hit by a large asteroid. Even asteroids less than 150 metres in size can cause massive local damage. However, such damage can be minimised with advance warning of the impact. NASA's Asteroid Terrestrial-impact Last Alert System (ATLAS) tries to find such small asteroids days or weeks before they hit Earth. A new telescope for ATLAS is currently being built in Sutherland.

Construction of the ATLAS telescope in Sutherland.

Traditionally all observations used to be carried out at a telescope. But all the SAAO telescopes at Sutherland are now remotely operable, mostly from remote observing stations the SAAO in Cape Town. Due to Covid-19, a few separate observing stations were set up, so that each telescope can be operated by one person at a different location on the SAAO's Cape Town site. A few SAAO observers even operate the telescopes from home!

The Intelligent Observatory programme, which is currently under development at the SAAO, aims to integrate all the telescopes at Sutherland to work together as a giant artificial intelligent machine deciding on its own which interesting astronomical targets should be observed with which telescope and instrument.

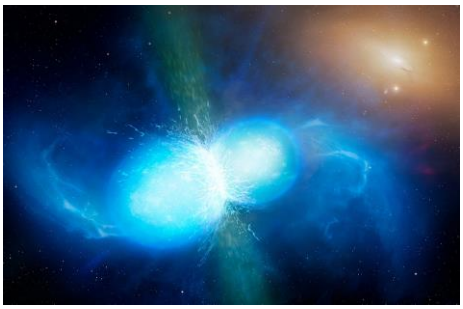
General astronomy updates

One of the predictions of Einstein's Theory of General Relativity was that moving bodies can cause gravitational waves, ripples in space and time themselves. Physicists had been trying to detect gravitational waves for decades when finally on 14 September 2015 the gravitational wave detector LIGO for the first time picked up a gravitational wave signal, caused by two colliding black holes 1.3 billion lightyears away.

This opened a completely new window for looking into the Universe. The next decisive event took place about two years later. On 17 August 2017 LIGO and another gravitational wave detector, Virgo, detected gravitational waves from two colliding neutron stars. A few seconds later a satellite for high energy radiation detected a signal as well. For the first time an astronomical event was seen both in gravitational waves and light.

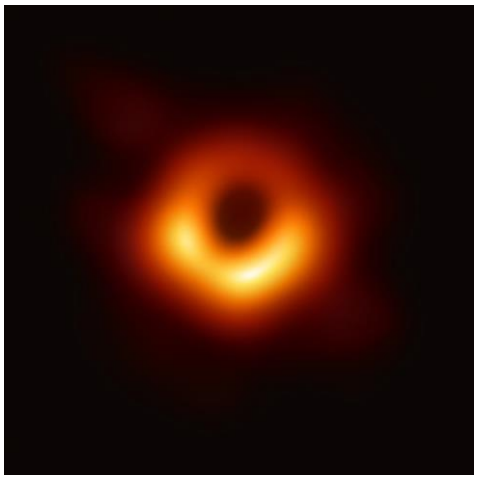
A frantic search for the location of the source in the sky started, and once the source had been found, telescopes all over the world were pointed at it. South Africa played an important part in this endeavour; some of the earliest spectra of the source were taken by telescopes in Sutherland. You can watch a short movie on this at https://youtu.be/JjCVNdeEoQk.

While no light can escape from a black hole, if matter is falling into the black hole, you can see light emitted by this matter before it



Artist's impression of two colliding neutron stars.

reaches the event horizon. So in principle you can see the event horizon. However, black holes are so far away that it was impossible for telescopes to resolve it. But in April 2017 eight radio telescopes around the Earth looked at the galaxy M87 at the same time for several nights, thus effectively acting as a telescope the size of the Earth. This gave them the necessary resolution to see the event horizon and its surroundings - and what they saw confirmed the predictions made by Einstein's Theory of General Relativity.

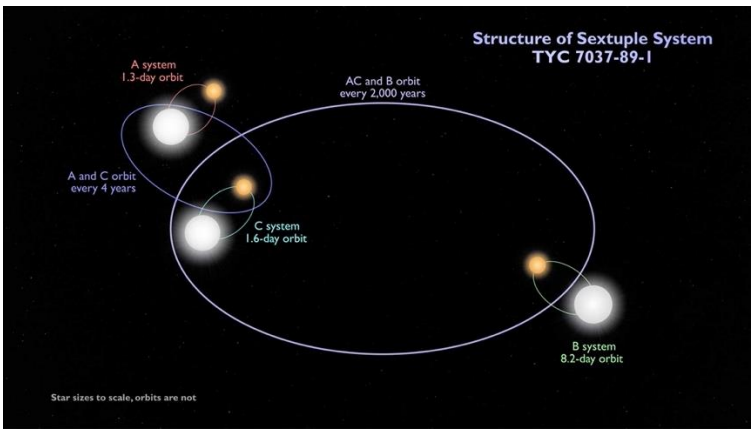


The black hole at the centre of the M87 galaxy.

The first confirmed object from interstellar space to visit the solar system, 'Oumuamua, was discovered on 19 October 2017. 'Oumuamua may have been wandering through the Milky Way for hundreds of millions of years before its chance encounter with us. It is probably made of rock and possibly metals, and with its length of 400 metres and width of maybe just 40 metres, it is shaped like nothing in the solar system. Its name 'Oumuamua is Hawaiian and means a "messenger from afar arriving first."

Artist's impression of 'Oumuamua.

Launched on 18 April 2018, the Transiting Exoplanet Survey Satellite (TESS) has been scanning the sky for exoplanets orbiting dwarf stars. To date (March 2021) it has found 120 planets, with 2562 candidates still to be confirmed. TESS made other discoveries as well. An example is TYC 7037-89-1, the first six-star system ever found in which all stars participate in eclipses.



TYC 7037-89-1, a six-star system of eclipsing binaries. The image is not to scale.

Image sources:

Pluto: https://www.nasa.gov/feature/new-horizons-top-10-pluto-pics

Saturn: https://solarsystem.nasa.gov/news/13141/cassini-top-images-2017/

Chang'e 4 lander: https://en.wikipedia.org/wiki/Chang%27e_4#/media/File:Chang'e_4_lander.jpg

Perseverance landing: https://mars.nasa.gov/resources/25609/high-resolution-still-image-of-perseverances-landing/

HRS: Lisa Crause

Laser comb: Lisa Crause

Galactic centre: https://www.sarao.ac.za/gallery/meerkat/

Galaxies: https://www.sarao.ac.za/media-releases/south-africas-meerkat-peers-deep-into-the-universe/

Construction of ATLAS: Willie Koorts
(https://www.facebook.com/SAAOnews/photos/a.233984359978834/3571483189562251/?type=3&theater)

Neutron star merger:
https://en.wikipedia.org/wiki/Neutron_star_merger#/media/File:Eso1733s_Artist's_impression_of_merging_neutron_stars.jpg

Black hole image: https://en.wikipedia.org/wiki/Event_Horizon_Telescope#/media/File:Black_hole_-_Messier_87_crop_max_res.jpg

‘Oumuamua: https://solarsystem.nasa.gov/asteroids-comets-and-meteors/comets/oumuamua/in-depth/

TYC 7037-89-1: https://exoplanets.nasa.gov/news/1672/discovery-alert-first-six-star-system-where-all-six-stars-undergo-eclipses/