YOUR GUIDE TO THE UNIVERSE

NRF National Research Foundation | SAASTA South African Agency for Science and Technology Advancement

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The Sun

We look at the Sun rising every day. It's bright, it's big and it warms us up. Our Sun happens to be the brightest object in our Solar System and naturally we are really curious to know more about it.

The Sun's heat and light provide the energy for life to exist on Earth. The Sun is a giant ball of extremely hot hydrogen and helium gases, nearly 150 million kilometres away. It is gigantic compared to the Earth. If you think of the Sun as a football, Earth would be the size of the head of a match. It is only because the Sun is so far away that it appears to be the same size in the sky as our Moon. The Moon is actually much smaller than our Earth, but much closer to Earth than the Sun is.

The Sun is so extremely hot - nearly 16 million degrees centigrade at the centre and 6 000°C on the surface. In the hot, dense core of the Sun hydrogen atoms get squashed into each other to produce helium atoms. This releases enormous amounts of energy, which escapes as heat and light. The Sun also produces X-rays and ultraviolet rays that are harmful to life, but most of these rays get soaked up by the Earth's atmosphere and do not harm us.

Scientific research has shown that the Sun and planets formed about 4,6 billion years ago out of a big cloud of gas and dust. All the planets, asteroids and comets that orbit the Sun, including the Earth, formed at the same time.

WARNING!

Never look directly at the Sun! It is even more dangerous to look at the Sun through a pair of binoculars or a telescope. You will be blinded for life! Don't even look at the Sun through sunglasses.

Photo of Solar corona (left) taken by Fred Espenak and one taken by Luc Viatour (right) during the total eclipse of 1999

Why Do We Study the Sun?

Our Sun gives us light, heat and energy. It may seem that energy comes from other sources such as gasoline and electricity but one of the major source of energy for the Earth is nothing else but the Sun. Without the Sun life on Earth would not exist. It would be so cold that no living thing would be able to survive and our planet would be completely frozen.

The Sun is a normal star. It is much closer to us than any other star and by studying the Sun, we can therefore learn more about other stars. The better we understand other stars, the more we know about the Milky Way. From there we know more about other galaxies and in the end we learn more about the universe.

The Sun also plays the role of a big anchor which creates the gravity that keeps our planet and the other planets of the Solar System from flying off into inter-stellar space.

Our Sun changes constantly. It has the largest eruptions in the Solar System. These eruptions can be so large that their effects can reach our planet and cause serious damage by disrupting satellites and other communication devices. Our TV may be disrupted, our cell phones drop calls and if an astronaut happens to be on the sunlit side of the Moon when the Sun erupts, he or she would be in great danger.

The National Aeronautics and Space Administration (NASA) of the United States uses satellites such as the Solar and Heliospheric Observatory (SOHO), to predict these eruptions so that we have a warning of only a day or two to protect our expensive communication devices during a solar eruption. SOHO is just one of the instruments that NASA uses to help scientists understand our Sun better along with other satellites and large observatories on Earth.

Students of Parkland Magnet School in Rockville, MD trace sunspots using sunspotters.

Photo credit: NASA/Silvia Stoyanova.

Top 10 Facts about the Sun

1. Never forget that the Sun is a star. The Sun provides us with energy, which sustains life on our planet. It gives rise to the seasons, the harvests and even the sleep patterns of all living creatures on Earth. This makes it extremely important for the continued existence of life on Earth.
2. The Sun is the closest star to our planet. Why do we see it so much bigger and brighter than stars? Imagine two cars on the road during the night with their headlights on. One car is closer to you and the other one is further away. Which headlights would seem brighter and bigger?
3. Remember - even though it looks to us as if the Sun goes around the Earth, the real situation is that the Earth goes around the Sun.
4. The Sun is way bigger than the Earth. For those of you who are curious, the Sun's diameter is 1 392 000 kilometres and the Earth's diameter is 12 756 kilometres. You could get, more than 100 Earths side by side across the Sun and it could hold more than a million Earths inside its volume.
5. DON'T TOUCH THE SUN! IT'S HOT! The Sun's average surface temperature is 5 700°C compared with the Earth's average temperature of 20°C. The Sun's core is about 16 million degrees centigrade.
6. The Sun is approximately 150 million kilometres away from the Earth.
7. How old is the Sun? The Sun is calculated to be 4.5 billion years old, a number so large that it is very difficult for the human brain to comprehend.
8. The Sun will burn out one day. It is predicted that when the Sun reaches the end of its life, it will swell up to a few hundred times its current size. It might just be big enough to engulf/swallow the Earth. But this is no reason for concern, since it will take another 5 billion years for it to happen!
9. The Sun rotates on its axis approximately once every 25 days. The Sun is made of gas, which is why its different parts rotate at different speeds. The fastest rotation is around the equator and the slowest rotation is at the Sun's polar regions - more than 30 days.
10. The Sun changes. No matter when or where we look at the Sun, we will always see something interesting. Scientists observe these changes by watching the sunspots. These are dark spots which appear on the surface of the Sun. They are cooler areas than the rest of the Sun's surface and are produced by strong magnetic fields. They increase and decrease on a regular cycle of around 11 years even though the lenghth of individual cycles varies considerably.

A Closer Look at the Sun

We know that the Earth's structure consists of different layers. The Sun also has layers but unlike the Earth, the Sun is entirely gaseous - there is no solid surface.

When studying the structure of the Sun, solar physicists classify the layers into four domains:

The Interior

The interior of the Sun includes the core, the radiating layer (which has an insulating effect that helps maintain the high temperature of the core) and the convective layer through which energy is transported to the surface by convection (as opposed to radiation).

The Surface Atmospheres

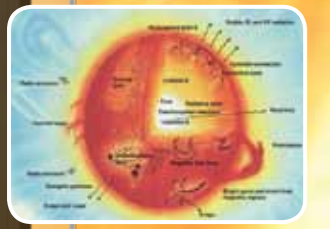
These comprise the photosphere (the coolest part of the Sun that we see with our eyes) and the chromosphere which although being colourful, cannot be seen because it is outshone by the brighter light from the photosphere. When a solar eclipse occurs, the reddish chromosphere is seen briefly just before and after the total eclipse.

The Corona

This is the part of the Sun that can be seen when the brilliant disk of the Sun is blocked by the Moon during the total eclipse. It is said to be the source of X-rays which do not penetrate Earth's atmosphere and extends millions of kilometres into space.

The Solar Wind

This is a wind made up of atomic particles such as electrons and protons blown away from the Sun. It extends to the outer regions of the solar system. The solar wind blows the tails of comets away from the Sun which is why comet tails always point away from the Sun and do not extend behind the direction of the comet's path.



Is there any difference between the Sun and a planet or a moon?

There are a number of ways in which the Sun differs from a planet or a moon. Some of these are:

- the Sun radiates heat and light. Planets and moons absorb and reflect heat and light coming from the Sun.
- the Sun is very much brighter than any planet or moon. As a result it is considered a phenomenal source of energy. Remember, without the Sun, life would not exist.
- The Sun is very much larger than any other planet in our Solar System. Its diameter is said to be ten times greater than that of Jupiter, the largest planet in our Solar System and more than a hundred times larger than our planet Earth!

The Solar System

The Sun is at the centre of or Solar System. Orbiting around the Sun is its family of major planets, many with their own moons. There are also dwarf planets and thousands of other smaller objects such as asteroids, comets and meteors. The strong pull of the Sun's gravity holds it all together.

The Solar System is shaped like an almost flat disk which means that all the planets orbit in roughly the same plane.

Our Sun is just one of about 100 000 million stars that make up our Milky Way galaxy. The Milky Way is one of many such star systems, each called a galaxy. The Universe consists of at least 100 000 million galaxies, each containing their own stars, planets and clouds of gas and dust, out of which stars and planets are born.

The Solar System consists of:

- the Sun
- eight planets
- five known dwarf planets
- many moons orbiting the planets and the dwarf planets
- thousands of Solar System bodies
- interplanetary dust.

Neptune

Uranus

Saturn

Jupiter

Mars

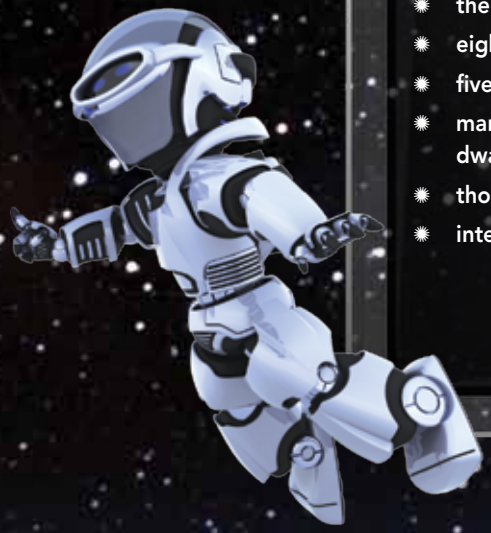
Earth

Venus

Mercury

The Sun

Not to scale



The Planets

Although all the planets of our Solar System were formed at the same time and from the same cloud of gas and dust, there are great differences between them.

The four inner terrestrial (Earth-like) planets are Mercury, Venus, Earth and Mars and are mainly made of rock and metal. Beyond Mars lie Jupiter, Saturn, Uranus and Neptune which are giant gas planets. Distant dwarf planets do not fit into any of these groups. They are probably made of ice and rock.

Mercury is the closest planet to the Sun Neptune is the farthest from the Sun. The phrases in the textbox help you to remember the order of the planets: Mercury, Venus, Earth, Mars, Asteroids, Jupiter, Saturn, Uranus, Neptune.

How to Remember the Planet Names

The planets are named after ancient Greek and Roman gods. An easy way to remember these names is to remember the sentence: "Many Very Elderly Men Just Sleep Under Newspapers" or "My Very Excellent Mother Just Served Us Noodles" or "Mary's Violet Eyes Make John Stay Up Nights".

Mercury

Mercury is the closest planet to the Sun. It was named after the Roman god, Mercury, the mercurial messenger of the other gods. The planet Mercury moves quickly around the Sun which causes it to frequently be seen moving between our morning and evening skies. This is similar to the god Mercury's swift flights from place to place. This is why the fast moving element Mercury is also known as quicksilver – a name that the metal mercury used to be known by.

Mercury is the smallest of the eight planets. Due to a combination of its elliptical orbit and its slow rotation speed, Mercury's year is shorter than its day! Due to it being closest to the Sun, Mercury has the shortest year in the Solar System – only 88 days. Its day – sunrise to sunrise - takes 176 Earth days. During its long daytime, its surface becomes extremely hot and at night its surface is icy cold. It is covered with mountains, valleys and craters and looks like our Moon. Humans would not be able to live on Mercury.

Mercury fact file

- Diameter: 4 880 kilometres, a bit bigger than Earth's Moon.
- Average distance from the Sun: 58 million kilometres
- Rotation period: 59 days
- Day/night: 176 Earth days
- Length of year: 88 Earth days
- Temperature: -185˚C to 467˚C
- Satellites:0

Venus

Venus is the hottest planet in the Solar System. It was named after the Roman goddess of love and beauty because it looks like a beautiful gem in the sky. In reality, Venus is a hot, rocky world under an atmosphere almost entirely made up of carbon dioxide. Its thick atmosphere holds in the Sun's heat.

The surface of Venus is completely hidden by dense, white clouds. However, we know what its surface looks like thanks to information received from space radar and from photographs taken by two spacecraft that landed on its surface, surviving only long enough to send back data and images. There are high mountains, craters and volcanoes on Venus.

Venus and Earth are similar in size. Venus is also the planet that approaches closest to Earth. Venus is unusual because its rotation on its own axis is in the opposite direction to that of all the other planets.

Venus fact file

- Diameter: 12 104 kilometres, about 0,8 times the size of the Earth
- Mean distance from the Sun: 108 million kilometres
- Day/night: 117 Earth days
- Length of year: 225 Earth days
- Temperature: 460°C on average
- Satellites:0

Earth

Our planet is the largest of the rocky planets and is named Earth from the name we use for the ground in which plants grow. As far we know, the Earth is unique in the Solar System for two reasons: it has liquid water on its surface and it supports life. If you look at Earth from space it looks like a blue and white sphere. Before the time of space travel and satellite images, people were not able to see Earth like this. Without pictures it is hard to imagine that the Earth we live on is a ball-shaped planet travelling through space. Earth is not quite round. It bulges at the Equator and flattens at the Poles. This shape is called an oblate spheroid.

The time it takes the Earth to complete one orbit around the Sun is called a year. A year is 365 days, 5 hours, 48 minutes and 46 seconds long – the extra hours being nearly a quarter of a day. We divide the year into 365 days, but every fourth year an extra day is added to the calendar year to keep in step with the extra quarter day in each of the preceding four years. A year with an extra day – the 29th of February – is called a leap year.

Day and Night

As the Earth orbits around the Sun, it rotates on its own axis. This gives rise to us seeing the Sun appear to move overhead from east to west. This naturally led mankind to believe that the Sun travelled around the Earth. Today we know that the Earth travels in an orbit around the Sun.

Earth's rotation on its own axis every 24 hours gives rise to the change between day and night.

The Seasons

The seasons – Spring, Summer, Autumn and Winter – occur because the Earth's rotation axis is tilted at 23.5° to the plane of its orbit around the Sun. The direction and angle of the tilt do not change. This means that for six months of the year from September to March the southern hemisphere is tilted towards the Sun, most prominently in December.

Earth fact file

- Diameter: 12 756 kilometres
- Mean distance from the Sun: 150 million kilometres
- Day/night: 24 hours
- Length of year: 365 Earth days and 5 hours
- Temperature: maximum 58°C; minimum -89°C
- Satellites: 1 – the Moon

At this time in South Africa the Sun passes nearly overhead at midday giving us lots of heat. An effect of the tilt is an increase in the length of the daylight hours. For the other six months from April to September, the northern hemisphere tilts more towards the Sun while the southern hemisphere tilts away from the Sun. During mid-winter the Sun no longer shines from overhead but passes from east to west only 45° above the northern horizon. These effects combine to give us less daylight hours, thus less sunshine, thus colder weather, especially in mid-winter around June and July.

Mars

The fourth planet Mars was named after the Roman god of war. It shines very brightly when closest to the Earth, but at other times its orbit takes it so far away, making it appear much dimmer. Mars has an orange-red colour and so it is known as the Red Planet. Mars is the only planet chosen for possible exploration by humans because conditions there are more like those on Earth than conditions on any of the other planets are. There is evidence that Mars once had rivers, streams, lakes and even an ocean. Today the only water on Mars is either frozen in its polar caps or is underground.

Mars is smaller than Earth and has many craters and mountains. The highest mountain peak and some of the deepest valleys in the entire Solar System are found on Mars. The Martian mountain called Mons Olympus is more than twice the height of Earth's Mount Everest!

In recent years, unmanned spacecraft called space probes have landed on Mars. The probes, sent to Mars by Russia and by the United States of America, performed experiments to learn more about the surface and the carbon-dioxide atmosphere which, although very thin, blows up dust storms that at times encircle the planet.

Mars has two moons, called Deimos and Phobos. They might be the remnants of a larger moon that broke up many millions of years ago, but they could well be asteroids that have been captured by Mars.

Mars fact file

- Diameter: 6 794 kilometres, about half that of the Earth
- Mean distance from the Sun: 228 million kilometres
- Day/night: 24 hours 37 minutes
- Length of year: 687 Earth days
- Temperature: -133˚C to +27˚C
- Satellites: 2

Jupiter

Jupiter fact file

- Diameter: about 142 800 thousand kilometres
- Mean distance from the Sun: 778 million kilometres
- Day/night: 9 hours 55 minutes
- Length of year: 4 333 Earth days or 11,9 Earth years
- Temperature: -110˚C
- Satellites: 63 discovered by 2013

Jupiter is by far the largest planet in the Solar System, and was named after the Roman mythological king of the gods. It is so big that all the other planets can be squeezed inside it. Jupiter is the first of the gas giants, amongst the outer four planets of our Solar System.

Jupiter spins so fast that a day on the planet lasts less than 10 Earth hours. Jupiter is a huge ball of mostly hydrogen gas – about 90% and 10% helium gas; it does not have a solid surface – thus not qualifying to be called a terrestrial planet as the first four planets are. However, in its centre these gases are compressed to a very hot liquid called metallic hydrogen. Due to its 12 year long orbit around the Sun and its fast rotation, there are 10 475 days in Jupiter's year! Inhabitants of Jupiter would need a long and complicated calendar!

The bands we can see above and below its equator are areas of particular turbulence in its clouds. Large areas of swirling gases can be found in Jupiter's atmosphere. The largest of these areas is called the Great Red Spot and scientists have been watching this giant storm – wider than the entire Earth - rage for several hundred years. Bolts of lightning have also been seen in Jupiter's atmosphere.

Photographs taken by spacecraft have shown thin, dark rings around Jupiter. In February 2010 two new moons orbiting Jupiter were discovered bringing the total to 63 – yes, 63 moons around one planet! The four largest moons were discovered by Galileo Galilei with his small 2,5 centimetre diameter telescope in 1610. They are Io, Europa, Ganymede and Callisto. There are active volcanoes on the smallest of the Galilean moons Io, which orbits Jupiter in only one day. Europa is thought to have liquid water – perhaps harbouring life –under its icy surface. Ganymede is the largest moon in the whole Solar System.

The four Galilean moons can be seen using normal household binoculars, the inner moons orbiting fast enough for us to see the movement during the course of an evening.

Saturn

This planet was named after the Greek god Saturn, because Saturn was the father of Jupiter and not because of any characteristics of Saturn that could be seen. Like Jupiter it was discovered in 1610 by Galileo, who thought the rings were Moons. Through further investigations, we now know that Saturn is circled by a beautiful set of rings around its equator. Saturn was the last of the planets known in bygone days because the planets further out could not be seen with the naked eye.

The rings are made up of chunks of water ice, rocks and dust that range from specks to the size of a house. One of several theories astrophysicists have says that the rings are the remains of a small orbiting moon that was ripped apart by nearby Saturn's strong gravitational attraction.

Saturn is also a gas planet. Even though, like Jupiter, it also takes about 10 hours to rotate once on its own axis, its lower density causes its equator to noticeably bulge outward. There is a flattening of the poles giving Saturn an oblate spheroid shape, much like that of the Earth but much more exaggerated. White spots on Saturn's surface are powerful storms.

Sixty-one moons have been discovered in orbit around Saturn so far. Its 2nd largest moon Titan has a thick nitrogen atmosphere that makes it an attractive exploration destination. In January 2005, the Huygens space craft plunged through Titan's atmosphere and transmitted images back to us. Scientists think that conditions on Titan are like those on Earth 4,6 billion years ago. Titan is the furthest place from Earth where a spacecraft has ever landed. Titan is also the only moon in the Solar System to have a dense atmosphere - one even thicker than Earth's atmosphere. Saturn is the second largest planet in the Solar System.

Here are the names of 30 of Saturn's moons. Try and find them in this word puzzle where names are written horizontally to the left or right, vertically up or down or even diagonal. See the solution on the last page of this booklet – but not before trying for at least 60 minutes!

A	S	U	E	H	T	E	M	O	R	P	B	N	A	P
M	U	N	D	I	L	F	A	R	I	C	D	E	G	F
I	T	A	I	E	N	C	E	L	A	D	U	S	I	H
M	T	R	J	A	N	U	S	T	P	H	O	E	B	E
A	U	O	I	K	L	M	L	H	E	L	E	N	E	P
S	N	D	R	J	N	A	P	Q	T	H	R	Y	M	I
O	G	N	A	R	S	A	K	S	U	T	V	M	H	M
U	B	A	Q	A	N	R	A	I	S	W	X	I	Y	E
O	S	P	Y	L	A	C	L	C	V	K	D	R	P	T
T	I	T	A	N	S	Y	B	D	Z	I	A	E	E	H
S	F	H	G	Y	S	T	I	U	H	I	U	D	R	E
E	J	L	H	K	O	O	O	M	N	L	X	Q	I	U
L	P	T	R	Q	N	V	R	H	E	A	W	Y	O	S
E	E	A	C	E	R	R	I	A	P	O	B	D	N	E
T	A	R	V	O	S	Z	X	P	A	A	L	I	A	Q

Saturn fact file

- Diameter: 120 000 kilometres
- Mean distance from the Sun: 1 433 million kilometres
- Day/night: 10 hours 14 minutes
- Length of year: 29,5 Earth years
- Temperature:-140˚C
- Satellites: 61 (as of 2013)

Saturn's moons word search

Mimas	Enceladus
Tethys	Dione
Rhea	Titan
Hyperion	Iapetus
Pan	Atlas
Prometheus	Pandora
Epimetheus	Janus
Calypso	Telesto
Helene	Phoebe
Ymir	Paaliaq
Siarnaq	Tarvos
Kiviuq	Ijiraq
Thrym	Skadi
Mundilfari	Erriapo
Albiorix	Suttung

Uranus

When Uranus was discovered by William Herschel in 1781, he wanted to name it George after the then English king. Fortunately sanity prevailed and the name Uranus was chosen, not so much because Uranus was the god of the skies but because Uranus was the father of Saturn. Note that this was the first recorded discovery of a planet – all the other planets had been known since mankind evolved the ability to contemplate his surroundings.

Whereas Earth is tilted by 23.5° from the vertical, Uranus tilts over by nearly 90° which means that it lies on its side! Uranus' odd tilt may be the result of a powerful collision with another large object soon after it had formed. The effect is that each pole spends about 40 years in constant summer sunlight and then another 40 years in winter darkness.

We did not know much about this distant planet until the space probe Voyager 2 flew past it in 1986. Uranus also has rings but much less dense than those of Saturn. The planet itself is made up mainly of hydrogen and helium gases. It has a rocky core and there may be an ocean of water/ammonia beneath its clouds.

Uranus has 27 known moons as of 2013. Notable about these moons is that they are smaller than the moons orbiting the gas giants. The names of these moons were chosen to honour Shakespeare – they are named after characters in Shakespeare plays. The largest moons are Titania and Oberon, both named after characters in A Midsummer Night's Dream. For comparison Earth's Moon is 3 476 kilometres in diameter while Titania is less than half that diameter – 1 576 kilometres.

Uranus fact file

- Diameter: 51 000 kilometres
- Mean distance from the Sun: 2 876 million kilometres
- Day/night: 17 hours 14 minutes
- Length of year: 84 Earth years
- Temperature: -197°C
- Satellites: 27 discovered by 2013

Neptune

Seeing that Uranus was the god of the skies, the second planet to be discovered was named after the Roman god of water and the ocean – Neptune. Its discovery in 1846 was "by the point of a pen" as described by the director of the observatory where its French discoverer Urbain Le Verrier worked. Le Verrier had calculated where an 8th planet should be, based on the way Uranus was being ever so slightly gravitationally pulled out of its expected orbital path. The new planet was found exactly where he predicted it would be! Mathematics – the powerful language of the Universe!

In 2011 it was 165 years since Neptune's discovery which is the period of this planet's orbit around the Sun – in other words, its year. This meant that in 2011 it was at the same position amongst the background stars as it was when Le Verrier discovered it.

Neptune has a large storm raging on its surface, much like Jupiter. It is called the Great Dark Spot. This storm, discovered by Voyager 2, is also large enough to contain the Earth.

We know of 13 moons orbiting Neptune, the largest being Triton, two-thirds the diameter of Earth's Moon.

Neptune fact file

- Diameter: 49 500 kilometres
- Mean distance from the Sun: 4 503 million kilometres
- Day/night: 16 hours 6 minutes
- Length of year: 165 Earth years
- Temperature: -210°C
- Satellites: 13 discovered by 2013

Pluto and Dwarf Planets

What on Earth happened to Pluto? Powerful telescopes have been discovering similar Pluto-sized objects beyond Pluto in a region called the Kuiper Belt. It is estimated that many more of these smaller objects will be discovered. The question arose: Should we also call these new bodies planets and end up having 100 planet names to remember, or should we create a new class of Pluto-like objects? The sensible - although emotionally traumatic - decision was made in 2006 to place Pluto into a new category called dwarf planets.

Another two objects discovered beyond Neptune, called Haumea and Makemake, have also been classified as dwarf planets. It is likely that there will be many more dwarf planets in the future as the sky is more fully explored. All of the dwarf planets that we know of so far are smaller than our Moon.

The definition of a "dwarf planet" is a celestial body that:

a) is in orbit around the Sun,

b) has sufficient mass to become nearly round in shape,

c) has not cleared its orbit of other celestial bodies (by gravitationally absorbing them or flinging them out of its orbit) and

d) is not a satellite (or moon) of another celestial body.

Pluto was discovered by Clyde Tombaugh in 1930. An eleven year old girl, Venetia Burney, suggested it should be named Pluto after the god of the underworld, seeing as this newly discovered celestial body was dark and had been hiding away for so long.

Being so distant, discoveries continue to be made about Pluto. Charon was initially thought to be its one moon, but as recently as 2012 a fifth moon was discovered! Much more will be known about Pluto when the New Horizons spacecraft flies dramatically past it 2015. Stay tuned for the breaking news!

Pluto fact file

- Diameter: 2 306 kilometres
- Mean distance from the Sun: 5 874 million kilometres
- Day/night: 6 Earth days and 9 hours
- Length of year: 246 Earth years
- Temperature: -230˚C
- Satellites: Five known by 2013

The Five moons of Pluto

Image: NASA, ESA and M Showalter (SETI Institute)

Asteroids

Diagram showing the Asteroid Belt between Mars and Jupiter

A Panorama of the Tswaing Crater north of Tshwane

Credit: Neville Young

Hills that are part of the ridge around the Vredefort Crater

Members of the Pretoria Centre of the Astronomical Society of Southern Africa watch the Sun rise over the ridge of the Tswaing Crater

Credit: Neville Young

Orbiting the Sun between Mars and Jupiter are millions of rocks from small chunks to the size of small moons. When some of the bigger ones were first detected, they looked like stars and so were named 'asteroids' from the Latin meaning 'like stars'. Of course, they are not at all like stars but rather are like planets. They should therefore have been called 'planetoids'.

Even though there are estimated to be many million asteroids, 'only' 310 thousand have been numbered and of those 'only' 16 thousand have been given names. Examples are 2001 Einstein and 1134 Kepler. An important one for South Africans is 4093 Bennett named after the late Pretoria based comet discoverer, Jack Bennett.

Even though there are many million asteroids, their average distance apart is a staggering million kilometres. Space is incomprehensibly huge!

Nevertheless, occasionally one asteroid physically or gravitationally bumps another one out of the belt sending it on a wildly eccentric orbit around the Sun. Some of these wild orbits cross Earth's orbit and during the past aeons some have hit the Earth. Modern automated tracking telescopes are detecting these Near Earth Asteroids (NEAs) so that mankind will at least have some warning and can take possible action if a collision is forecast.

The largest known asteroid is the 950 kilometre diameter Ceres. Smaller asteroids usually have irregular shapes, like potatoes for instance and are not necessarily round.

The largest asteroid impact on Earth was 2 billion years ago in what is now the Vredefort region in the Free State, 100 kilometres south of Johannesburg. The crater was then noticeably deeper with bigger surrounding hill-sized ridges. Erosion over the years has worn the ridges away and filled the crater leaving an 85 kilometre wide ring of hills around Vredefort.

Tswaing, 40 kilometres north of Tshwane, is a 1 kilometre wide crater made only 200 000 years ago by a 60 meter wide asteroid. Have you visited either of these impact sites?

Moon

The Moon is the Earth's only natural satellite and is spelled with a capital 'M' to differentiate it from the known 168 moons in the Solar System. The Moon is a rocky body orbiting our planet at a mean distance of 384 000 kilometres. Like the planets, it produces no light of its own, but we can see it because it reflects the light from the Sun. The illuminated shape that we see depends on where the Moon is in its orbit around the Earth. A fascinating view of the Moon is through binoculars. Try it!

Due to the Moon having a rotation rate on its own axis the same as its orbital period around the Earth, we always see the same side of the Moon. The side of the Moon we cannot see is sometimes erroneously referred to as the Dark side of the Moon. In the same way that the illumination of the near side waxes and wanes, so too does the illumination on the Moon's far side.

The Moon's surface has many craters, formed by large bodies such as comets and asteroids that crashed into it between 3 and 4 billion years ago. Apart from the craters, the Moon's surface is like a desert with plains, mountains and valleys. The Moon has no atmosphere, so there is no air to breathe and no wind nor weather. Recently, water ice was discovered at the poles of the Moon, buried beneath dust on the surface.

The Moon is the only place in our Solar System, other than the Earth, where humans have been. On 20 July 1969 astronauts Neil Armstrong and Edwin Aldrin landed the Lunar Module of Apollo 11 on the Moon's surface. Armstrong became the first person to set foot on the Moon. A total of twelve astronauts in 7 missions landed on the Moon between 1969 and 1972. Apollo 13 developed life-threatening problems on the way to the Moon and only just managed to bring its astronauts home alive. The dramatic story is re-enacted in the movie 'Apollo 13'.

Moon fact file

- Diameter: 3 476 kilometres
- Mean distance from Earth: 384 000 kilometres
- Day/night: 29,53 Earth days
- Temperature : -170˚C min, +120˚C max.

Meteoroids, Meteors and Meteorites

Seeing the streak of a shooting star across a dark sky is always exciting. What are shooting stars?

Space is full of bits and pieces of the matter out of which our Solar System formed. They have orbited the Sun for 4 thousand 500 million years. Other bits and pieces come from comets which boil some of their material off as they round the Sun. The cast off particles travel in the comet's orbit in huge swarms. Often the Earth crosses the path that a comet once travelled and hundreds of these particles enter its atmosphere. Travelling at up to 40,000 kilometres per hour, the friction as they push through the air causes them to heat up and vaporise in a brilliant streak of light. The streak is called a meteor – commonly known as a shooting star. Before the particle can be seen as a flaming meteor, it is known as a meteoroid. If this meteoroid is big enough to survive being a meteor, it will reach the surface of the Earth where it is then called a meteorite.

Meteors burn up at a height of about 60 kilometres from the Earth's surface and – believe it or not – are usually the size of a grain of sand! To top it all, about 100 tons of these grains of sand and other larger pieces impact the Earth every day! Space never fails to astound us.

Comets

Comets are lumps of ice and rock that orbit the Sun at the outer edges of our Solar System. Sometimes one of these lumps is knocked out of its distant path and its orbit changes from nearly circular to one where it careens in towards a close and hurried rendezvous with the Sun before taking a long and slow trip back to the outer reaches of the Solar System, either to turn around and repeat the Sunward journey or to leave our Solar System entirely.

As the comet nears the heat of the Sun, its ice melts and gas and dust are set free, which we see as a dramatic tail, reflecting the Sun's light. Such a tail can stretch for many millions of kilometres. We expect the smoke from a steam engine to blow behind the train. This happens because the smoke is held back by the air through which the train is moving. A comet's tail does not always trail behind it. There is no air in space to hold the gas and dust tail back, but there are winds of particles called the solar wind radiating from the Sun. This wind is substantial enough to blow the tail away from the Sun even if the comet is leaving the Sun, in which case the tail precedes the comet. The comet tail always points away from the Sun no matter in which direction the comet happens to be moving.

Some comets take thousands of years to orbit the Sun, while others take only a few years. Probably the most famous comet of all is Comet Halley, which returns every 76 years. Comets are usually named after the person who discovers them. Comet Halley was named after Edmund Halley (1656 - 1742), an English scientist.

Comet Bennett was a famous comet of the 20th century. It was discovered by Pretoria based South African astronomer Jack Bennett in 1969. These pictures show Jack Bennett and his stunning comet.

Stars

Stars beautifully stud our night skies. What are they?

We can learn about distant stars by looking at a star on our doorstep – the Sun. Like our Sun, a star is a ball of hydrogen and helium gas, squeezed so hard into the middle by gravitation that the gas heats up to the point where a nuclear reaction is triggered. The reaction releases huge amounts of energy in the form of heat and light, which we can sense, as well as other energy forms such as X-rays.

Our ancestors only had their naked eyes to look at the stars. There are 6 000 stars visible to our naked eyes.

Stars vary in temperature, brightness and size. Some are very hot and shine with a bluish light, while others are much cooler and look orange or red. These colours can be seen with the naked eye in some stars. Our Sun is an average star, slightly yellow in colour.

The brightness of a star as we see it depends on the type of star as well as its distance from the Earth. The brightest star in the sky is not the closest one to us. It is called Sirius and is much whiter and hotter than the Sun. The closest star to us (after the Sun of course) is called Proxima Centauri. It is small, dim and red. The astronomer Robert Innes discovered it from Johannesburg in 1915. It is the closest star to Earth (after our Sun). Proxima Centauri is one star in a group of 3 stars orbiting each other. The other two are much brighter and are so close to each other that our naked eyes see them as one very bright star which we call Alpha Centauri. The combination makes this star the 4th brightest star in our heavens. You can easily see Alpha Centauri. It is one of the 2 pointer stars that help us find the Southern Cross - the one further away from the cross.

A Hubble Space Telescope image of the very stunning planetary nebula called the Cat-Eye Nebula (NGC6543). The dying central star possibly produced this simple, outer pattern of dusty concentric shells by ejecting its outer layers in a series of regular convulsions.

Credit: NASA, ESA, HEIC and The Hubble Heritage Team cl/AURA). Taken from Astronomy Picture of the Day.

In most stars, after the nuclear fusion has used up all its fuel, gravity pulls the remaining material closer together. The star shrinks to become what we call a dwarf star. In fact, it may get to be only a few hundred kilometres wide when it finally stops radiating visible light.

Some stars can be up to 100 times as massive as the Sun, with much shorter lives measured in only millions of years, and the nuclear reactions lead to the creation of the elements which are life's building blocks – carbon, nitrogen, oxygen, sodium, magnesium, aluminium, silicon, sulphur and iron. In these massive stars, when there is no longer hydrogen and helium left to sustain the nuclear reaction, the star collapses in on itself. If the star is really big, the inward collapsing star rebounds in a massive explosion during which not only are the elements inside the star spewed out into space, but other elements like copper, zinc, silver, tungsten and gold are created.

These explosions are called supernovas from the Latin where 'nova' means 'new'. Supernovas appear to us as a new star not having been recorded in star charts prior to brightening or perhaps having previously been a very faint star. The last great supernova easily visible to the naked eye was in 1604. Supernovas can also be seen in other galaxies besides our Milky Way galaxy.

Any matter remaining after a supernova explosion is crushed by gravity to a very dense state equivalent to an object approximately 20 kilometres across. The pressure is so great that electrons and protons are squeezed together to form neutrons in the atoms. This star is thus called a neutron star.

If the collapsing star was very big, the collapse does not stop at the neutron star stage. The leftover matter is crushed until gravity is so strong that not even light can be radiated away. The matter disappears from view and becomes a black hole. Nothing can be detected from the black hole except its powerful gravitational

Exoplanets

Until late in the 20th century there was only speculation whether there were planets around other stars. The first confirmed exoplanet (condensed from the words extra solar planet) was discovered in 1992 and by 2013, 861 exoplanets had been confirmed while another 18,000 await confirmation. Exoplanets raise the possibility that life exists elsewhere in the Universe. Planets in the "Goldilocks Zone" – not too hot and not too cold – are of particular interest because they lie in a zone where life could possibly develop. There are currently 262 potential Goldilocks planets amongst the 18,000 potential exoplanets.

Galaxies

Galaxies are collections of gas, dust and a vast number of stars. Most are are generally shaped like a flat disk with spiral arms radiating out from the centre and others are elliptical. Galaxies range from a few thousand to a million light-years in diameter. Their appearance to us depends on whether we see them face-on or edge-on or from some angle in between.

Galaxies often exist in groups, referred to as clusters. Our galaxy belongs to a group of galaxies called the Local Group. Astronomers have discovered many thousands of other clusters of galaxies as far as we can see in the Universe.

A light-year is NOT a measure of TIME. A light-year is the DISTANCE that light travels in one year. This is a long way. Light reflected off the Moon reaches us only 1 second later. In one year light travels an incomprehensible 9.5 trillion kilometres!

The Milkyway Galaxy

Our Sun is only one of 100 billion stars in the Milky Way galaxy. Our Sun and Earth lie inside this galactic disk some two thirds of the way from the centre. On a clear, dark night you can often see the bright band of the Milky Way arcing across our skies in directions that depend on the time of day and year we see them. When you look at this band of stars, you are looking along the inside of the disk. When you look away from the band, you are looking up (or down) out of the Milky Way.

The Andromeda Galaxy is the nearest major galaxy to our own Milky Way Galaxy. It is similar in size and shape, to our galaxy and both have a number of dwarf galaxies orbiting them. You can see Andromeda with your unaided eyes but you will need a dark sky and someone to show you where to look. Two small, rather irregularly shaped galaxies nearer to the Milky Way galaxy called the Large and Small Magellanic clouds (because they look like tiny patches of cloud) can also be seen with the unaided eye. You may have even seen them before without knowing what you were seeing.

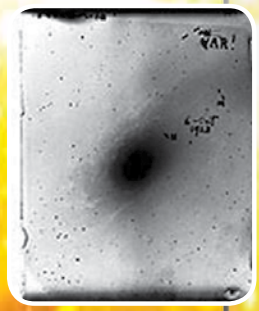
M100, a typical spiral galaxy

The Universe and the Big Bang

The Universe is a huge wide-open space that contains everything from the smallest particle to the biggest galaxy. The Universe is the totality of all space, time, matter and energy – an idea that is very foreign to our human minds. No one knows just how big the Universe is or even whether it does have a size. All we can say is how far we can see.

A major breakthrough in our understanding of the universe took place in the 1920's thanks to American astronomer Edwin Hubble. For centuries, astronomers believed that the Milky Way made up the entire universe. Hubble was among the first to show that the faint, fuzzy patches we see in the sky through telescopes are other galaxies, not distant parts of the Milky Way!

Hubble also realised that all galaxies are moving away from each other. The rate of expansion is measured using a spectroscope - an instrument that breaks up the white light from a star into its different colours. By carefully analysing the colours, spectroscopists can tell if an object is moving away from or towards Earth and how fast it is moving. Hubble also determined that the farther away a galaxy is, the faster it seems to be moving. These gave rise to the conclusion that space itself is expanding.



Based on this knowledge, Georges Lemaitre, a Belgian astrophysicist and Catholic priest, came to be known as the "Father of the Big Bang" by proposing in 1931 that the universe began as a single primordial atom of energy, something hot and dense that exploded, causing space itself to expand outwards.

Based on the rate of expansion, astronomers have calculated that this expansion started 13.7 billion years ago. This marked the beginning of the Universe as we know it.

Cosmology

Cosmology is the study of the overall structure of the universe. Like early astronomers from around the world, the ancient Greeks struggled to understand the universe.

The beginnings of modern science can be attributed to Galileo and to the British genius Isaac Newton. Newton was born in the same year that Galileo died. Isaac Newton took known facts and used mathematics to explain them. He developed mathematical laws that explained how objects move on Earth as well as in space. Newton explained the movement of orbiting planets as the result of motion along a straight line combined with the gravitational pull of the Sun. His laws are based on the idea that nothing is naturally at rest. He reasoned that all heavenly bodies are constantly moving, with no limits on space and time.

In 1917, Albert Einstein proposed a description of the universe based on his Theory of General Relativity. Einstein's theory inspired many other scientists, including Willem de Sitter in Holland and Alexandr Friedmann in Russia. In fact, much of today's cosmology is based on Freedman's solutions to the mathematical equations included in Einstein's Theory. Friedmann built on the General Relativity equations to develop models that helped explain the evolution of the universe.

Today cosmologists are concerned with the ultimate fate of the universe. Will it expand forever, expand to a certain size and stop, or will it stop and begin to collapse? Data suggesting that the universe is expanding at an increasing rate were published in 1998. For more than ten years astronomers had been studying the expansion of the universe by measuring the redshift and brightness of distant supernovae. By 1998, enough information had been gathered to lead scientists to the startling discovery that the expansion of the universe is not slowing down but is accelerating. The supernova data combined with information from other cosmological studies strongly suggest that the universe is filled with an unidentified form of energy (currently being called "dark energy" since we know nothing about it) that is causing the expansion of the universe to accelerate. If these observations and analyses turn out to be correct, the universe would be expected to continue to expand forever.

The Place of our Solar System in the Universe

In ancient times, the commonly and understandably accepted view was held that the Earth was the centre of the Universe with everything else revolving around it.

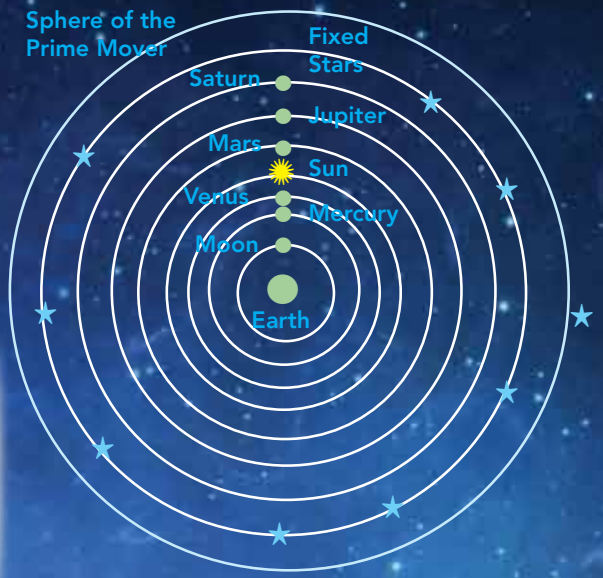
Aristotle, who lived from 384 to 322 BC, believed the Earth was round. He thought Earth was the centre of the universe and that the Sun, Moon, planets and all the fixed stars revolved around it. Aristotle's ideas were widely accepted by the Greeks of his time. The exception, a century later, was Aristarchus, one of the earliest believers in a heliocentric or sun-centred universe.

The first astronomer to make truly scientific maps of the heavens was Ptolemy 300 years later. Like most astronomers before him, he believed that the Sun, Moon and planets circled the Earth. He thought that each celestial body was fixed to a crystal sphere which held the body in place and rotated around the Earth. Ptolemy's view held that all stars were fixed in an unchanging, everlasting outermost sphere of the Universe.

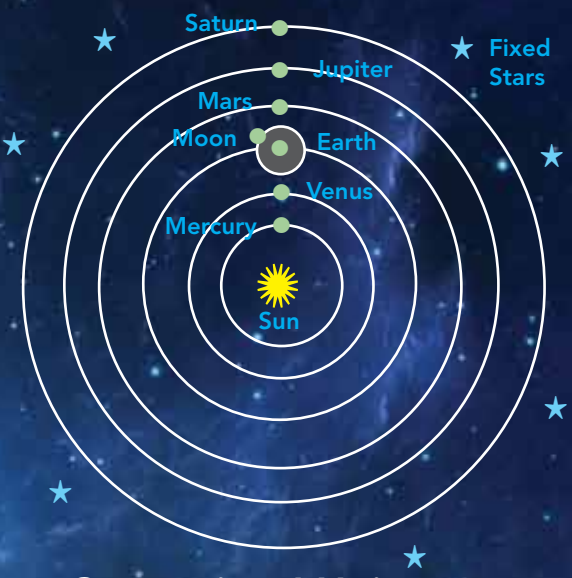
The Earth-centred view of the universe was widely accepted for about 1500 years. It was not seriously challenged until 1543 when Nicolaus Copernicus suggested that the Sun was at the centre of the universe.. The two events most responsible for eventual acceptance of Copernicus' views were Tycho Brahe's precise observations of the sky and Galileo's use of the telescope.

One night in 1572, Danish astronomer Tycho Brahe saw what he thought was a brilliant new star in the constellation Cassiopeia, a phenomenon we now refer to as a supernova. In 1604, a second supernova was seen. These discoveries caused scientists to seriously question the ancient belief that stars and the sphere in which they were fixed was unchanging. In 1609, Italian scientist Galileo Galilei heard about the invention of a telescope. He made one for himself and turned it on the heavens. One of his first discoveries was the four moons circling the planet Jupiter. Galileo's telescope revealed a miniature version of Copernicus' solar system, with the moons moving around the planet in simple, nearly circular orbits. This proved that bodies could and did orbit bodies other than the Earth. Galileo's discoveries forever changed the face of astronomy.

Now we know our planet is only one part of one solar system. Our Sun is just one of billions of stars in our galaxy. Our galaxy and countless others like it make up the Universe.



Aristotle's' Universe



Copernicus' Universe

Space Exploration

For many centuries, space exploration was unimaginable. Overcoming the pull of Earth's gravity requires a strong engine capable of accelerating a rocket for about 10 to 15 minutes before it reaches a distance of about 200 kilometres above the Earth's surface, where it can go into orbit and not fall back to Earth. In the twentieth century, the invention of powerful rockets made space travel possible.

The launch of a Soyuz rocket into space

SPACE EXPLORATION FACT FILE

- Rocket-propelled spacecraft were first seriously considered by a Russian, Konstantin Tsiolkovsky (1857 - 1935).
- The first rocket to use liquid fuel was built in 1926 by the American, Robert H. Goddard.
- 4 October 1957: the Soviet Union (USSR) began the age of space exploration with the launch of Sputnik 1, the first artificial satellite. Sputnik orbited the Earth in 90 minutes and stayed in space for six months.
- Sputnik 2 (USSR, 1957) launched the first living creature into space – a dog called Laika, but it died a few hours after launch due to overheating
- Explorer 1 (USA, 1958) was the USA's first successful satellite.
- Telstar 1 was the first communications satellite. Launched in 1962, it carried one television channel. Live television images could be sent to Europe from the USA for the first time.
- 12 April 1961: Yuri Gagarin (USSR) became the first man in space.
- 5 May 1961: Alan Shepard becomes the first American to reach space.
- Mariner 2 (USA) was the first successful spacecraft to visit a planet. It flew past Venus on 14 December 1962 and made temperature measurements.
- 16 June 1963: Valentina Tereshkova (USSR) became the first women in space.
- 8 March 1965: The first spacewalk takes place (Alexei Leonov, USSR).
- In 1966, Luna 9 (USSR) becomes the first spacecraft to make a soft landing on the Moon and radio pictures of the Moon's surface back to Earth.
- The first manned flight around the Moon takes place in December 1968 (Apollo 8, USA).
- 20 July, 1969: The USA's Apollo 11 flies to the Moon and releases the lunar module which lands on the Moon and from which Neil Armstrong stepped to become the first human to set foot on another celestial body.
- The Russian Salyut 1 became the first space station when it was put in orbit in 1971.
- 20 July 1976: The US probe, Viking 1, becomes the first to land successfully on Mars.
- First successful flybys of Jupiter and Saturn by the space probes Pioneer 10 and 11 in 1973 and 1979.
- In 1977 space probes called Voyager I and Voyager II were launched. Their missions were to reach Jupiter, Saturn, Uranus and Neptune and send pictures back to Earth. By now (2010) Voyager I has travelled 170 billion kilometres and is nearing the edges of the Solar System.
- 12 April 1981: The first launch of the USA's reusable spacecraft called a Space Shuttle.
- 24 April 1990: The Hubble Space Telescope is carried into orbit by the space shuttle Discovery.
- 2 November 2000: The first crew to stay aboard the International Space Station arrive.
- July-Sep 1997: Mars Pathfinder, the first Mars rover, explores the surface of Mars.
- 12 February 2001: Spacecraft Near Earth Asteroid Rendezvous NEAR soft lands on asteroid Eros after studying it from orbit..
- January 2004: Two Mars rovers, Spirit and Opportunity, land on Mars. Spirit stopped working in 2010 but Opportunity continues to explore Mars in 2013.
- 1 July 2004: Spacecraft Cassini enters orbit around Saturn to study the planet, its rings and moons, after a six year journey from Earth.
- 14 January 2005: Cassini's probe Huygens soft lands on Titan - the first landing on the moon of another planet.
- The Kepler Space Telescope- launched 7 March 2009, designed to detect extrasolar planets – exoplanets.
- New Horizons – launched 19 January 2006 – will fly by Pluto in July 2015.

Satellites and their Uses

A man-made satellite is a spacecraft placed in orbit around a planet. Thousands of satellites have been launched and are currently in orbit around the Earth and also around other planets, where they gather information about the Earth, other planets and the Universe.

- Satellites are launched into space to do a specific job. Some examples:
- Remote sensing satellites carry cameras that take pictures of the Earth.
- Weather satellites take pictures to help experts predict weather patterns and their movements.
- GPS (Global Positioning System) satellites carry special transmitters to help people work out exactly where they are.
- Communication satellites bounce messages such as telephone calls, television images and Internet information from one side of the world to the other.
- Space tourism satellites transport, transfer and care for people who want to holiday in space. This is a relatively new idea and only affordable to the super rich. The entrepreneur Mark Shuttleworth became the second space tourist and the first South African in space in 2002. Until 2013 there have been 7 space tourists.
- Military satellites are used for spying or to guide missiles.

A NASA satellite caught this image of fires in the Western Cape Province

South Africa and Space Exploration

Mike Melvill on Space Ship One

Mark Shuttleworth in space

The Fregat Upper Stage of the Soyuz Rocket with all payloads fully integrated onto it. The huge orange coated satellite is the Meteor M-1 and SumbandilaSat is the tiny black square on the left

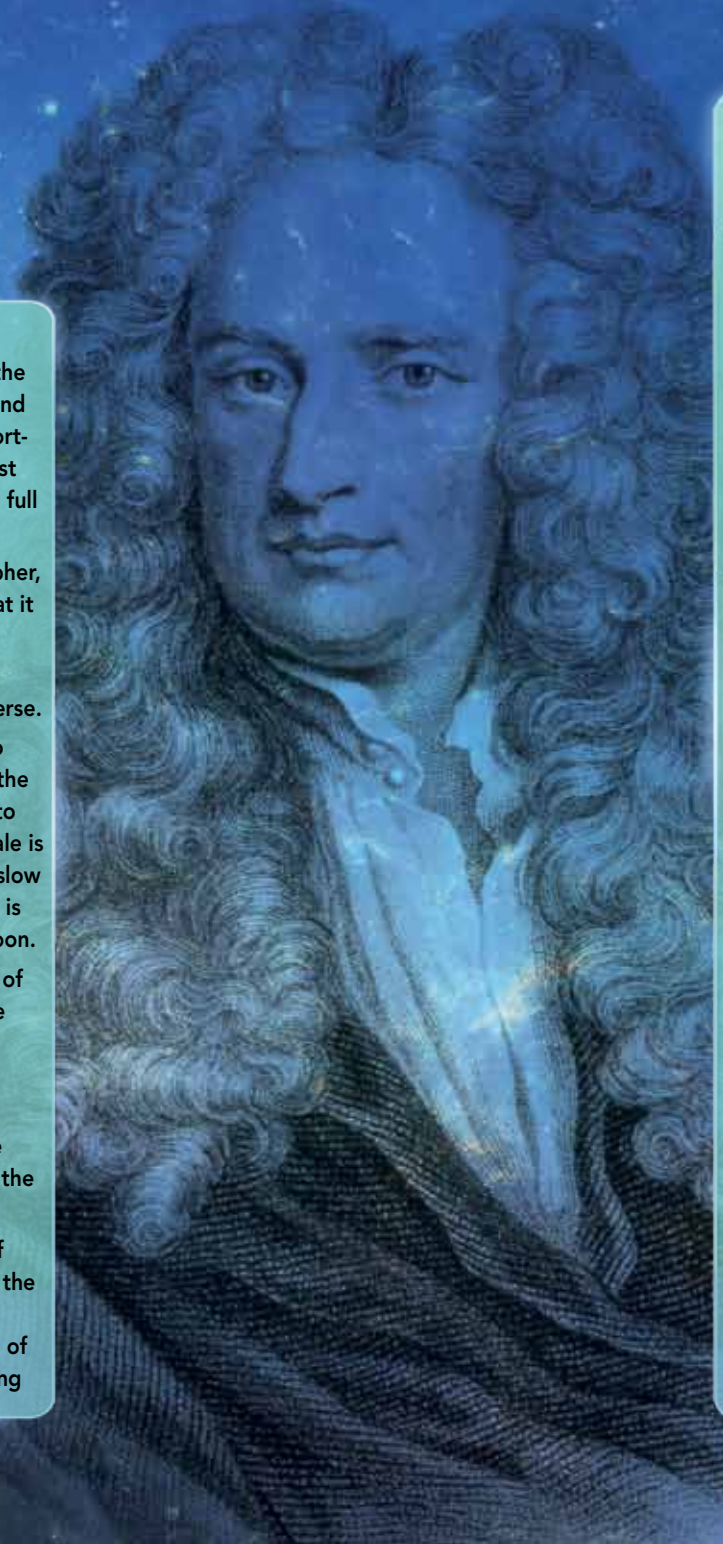
From the late 1950s to the 1970s South Africa operated spacecraft tracking stations for NASA. Deep Space Station 51 at Hartebeesthoek later became the Hartebeesthoek Radio Astronomy Observatory, while the STADAN site nearby became the CSIR's Satellite Application Centre.

Two South Africans have been into space. IT millionaire Mark Shuttleworth from Cape Town spent a week as a "space tourist" in the International Space Station (ISS). He was launched into space in a Russian Soyuz three-person space capsule from the Baikonur cosmodrome on 25 April 2002. Launching people into space is very expensive, so it was always government funded. However, modern technology has brought down costs and private companies are now developing manned space travel. The first privately built space-ship was Space-ship One, designed by Burt Rutan. The pilot who first took it all the way into space – higher than 100 kilometres above the ground – on a test flight on 21 June 2004 was Mike Melvill, who comes from Durban. SpaceShipOne can now be seen in the National Air and Space Museum in Washington D.C.

South Africa has also built two space satellites. The first, called Sunsat, was built by Stellenbosch University. It was launched on an American rocket in 1999. It operated for about a year. The second, called SumbandilaSat, was launched on 17 September 2009 on a Russian rocket. It was built by Sun Space and Information Systems in Stellenbosch. Sumbandila, meaning "lead the way" in the Venda language, carried powerful cameras onboard, able to distinguish objects as small as 6.25 meters from its 500 kilometre orbit above the Earth. Sumbandila ceased functioning in July 2011 after it was damaged by a blast of solar radiation.

South Africa has now formed its own Space Agency to promote the peaceful uses of space. Would YOU like to go into space?

Famous Astronomers



- Anaximander (611 - 546 B.C, Ionian) was a Greek philosopher who made the first detailed maps of the Earth and the sky. He knew that the Earth was round and believed that it was free-floating and unsupported. He measured its circumference and was the first to put forward the idea that celestial bodies make full circles in their orbits.
- Aristotle (384 - 322 B.C, Greek) the great philosopher, proved that the Earth is spherical and believed that it was at the centre of the Universe.
- Aristarchus (310 - 230 B.C, Greek) was the first to believe that the Sun was in the centre of the Universe.
- Hipparchus (190 - 120 B.C, Greek) is considered to be the greatest ancient astronomer. He compiled the first star catalogue and also came up with a scale to define the brightness of stars. A version of this scale is still used today. He discovered the precession, or slow rotation, of the direction of the Earth's axis, which is caused by the gravitational pull of the Sun and Moon.
- Al-Khwarizmi (780 - 850, Islamic) was the inventor of algebra. He performed detailed calculations of the positions of the Sun, Moon and planets and did a number of eclipse calculations.
- Nicolaus Copernicus (1473 - 1543, Polish) began a new era of astronomy when he concluded that the Sun was the centre of the Solar System instead of the Earth.
- Galileo Galilei (1564 - 1642, Italian) is the father of observational astronomy. In 1609, he heard about the Dutch invention of the telescope and built one for himself. He saw the craters, mountains and valleys of the Moon, noticed the huge number of stars making up the Milky Way, kept precise records of sunspot activity and the phases of Venus and discovered four moons orbiting Jupiter.
- Johannes Kepler (1571 - 1630, German) used the idea of elliptical orbits to describe the motions of the planets around the Sun.
- Giovanni Cassini (1625 - 1712, Italian) was the astronomer who first discovered the division in the rings of Saturn. He also found four moons orbiting Saturn and measured the periods of rotation of Mars and Jupiter.
- Isaac Newton (1643 - 1727, British) was a mathematician who described the astronomical models of Copernicus and Kepler. Newton showed that the laws governing astronomical bodies were the same laws governing motion on the surface of the Earth. Newton's scientific ideas still offer an accurate description of physics today, except for certain cases in which Einstein's Relativity Theory must be brought into consideration.
- Edmond Halley (1656 - 1742, British) became famous for predicting the 1682 appearance of a comet now named after him.
- Arthur Eddington (1882 - 1944, British) lead an expedition in 1919 during a solar eclipse to test a prediction made by Einstein based on Einstein's theory of general relativity. He made the first direct measurements of stellar masses and discovered the link between the mass of a star and its energy output. He also correctly suggested that nuclear fusion was the primary source of energy in stars.
- Albert Einstein (1879 - 1955, German) was probably the greatest mind of the twentieth century. His Special Theory of Relativity was proposed in 1905. In 1915, Einstein extended this further in the General Theory of Relativity, which includes the effects of gravitation.
- Edwin Hubble (1889 - 1953, American) discovered that faraway galaxies are moving away from us. This concept is a cornerstone of the Big Bang model of the universe.
- Stephen Hawking (1942 - , British) is another brilliant mind of the twentieth century. He combined the theory of general relativity and quantum theory in order to prove that black holes emit radiation and eventually evaporate.

Famous Women Astronomers

- Annie Jump Cannon (1863 – 1941, USA) was the first astronomer to classify the heavens systematically. She worked as an astronomer and published information about 225 000 stars.
- Henrietta Swan Leavitt (1868 – 1921, USA) discovered that a particular type of variable star known as a Cepheid could be used as a distance marker, making it possible to determine astronomical distances to other galaxies.
- Cecilia Payne-Gaposchkin (1900 – 1979, British). Her PhD dissertation, showing stars are made primarily of hydrogen and helium, was said to be one of the best in 20th century astronomy.
- Carolyn Shoemaker (1929 – , USA) had discovered 32 comets by 2013, more than any living astronomer. As of 2013 she has also discovered more than 800 asteroids.
- Jocelyn Bell-Burnell (1943 – , British) discovered pulsars in 1967 as a PhD student at Cambridge University, while supervised by Antony Hewish (who received the Nobel Prize for the discovery).

Women Astronomers in South Africa

There are many women playing a big role in astronomy in South Africa. It would not be fair to attempt to list them all, so these women below are a but a small sample.

- Dr Patricia Whitelock of the South African Astronomical Observatory uses the variable Mira stars to establish distances.
- Dr Sharmila Goedhart of South Africa's Karoo Array Telescope/Square Kilometer Array, KAT/SKA project is an expert on the formation of high-mass stars.
- Dr Claire Flanagan at the Johannesburg Planetarium studies neutron stars.
- Dr Catherine Cress at the University of the Western Cape is a cosmologist.
- Professor Renee Kraan-Korteweg heads the Astronomy Department at the University of Cape Town, UCT and studies galaxies.

Astronomers in South African History

Due to its ideal position in the southern hemisphere, South Africa has been a favoured destination for astronomers.

- Sir John Herschel the British son of William Herschel, the discoverer of Uranus, was not only an excellent observer but also a pioneer of photography as well as one of the fathers of education in South Africa. He spent a few years in South Africa.
- Thomas Maclear was an Irish-born South African astronomer who became Her Majesty's astronomer at the Cape of Good Hope. His geodetic work (see the Geodesy paragraphs towards the end of this booklet) led to the establishment of the Government Trigonometrical Survey Office of South Africa.
- David Gill – a Scottish astronomer - pioneered astronomical photography and became the president of the Royal Astronomical Society.
- Robert Innes, a Scottish born astronomer, showed that Proxima Centauri was the nearest star to the Sun. He was a brilliant self-taught mathematician and astronomer who left school at age 12 and became a Fellow of the Royal Astronomical Society when he was only 17.
- Dr Bernie Fanaroff studied radio galaxies and has classes of galaxies named after him. He now leads the Karoo Array Telescope project.
- Dr Thebe Medupe grew up near Mafikeng. He earned his MSc (cum laude) in Astrophysics and then obtained his Astrophysics Doctorate at the University of Cape Town. He founded and leads the University of North West's theoretical astrophysics programme and became a steering committee member of the National Astrophysics Space Science Programme in 2002.

These astronomers are just a small selection of the people who have enriched our astronomical heritage.

Astronomy In South Africa

History

South Africa has a rich heritage of ethno-astronomy and star lore within several of its many cultural groups.

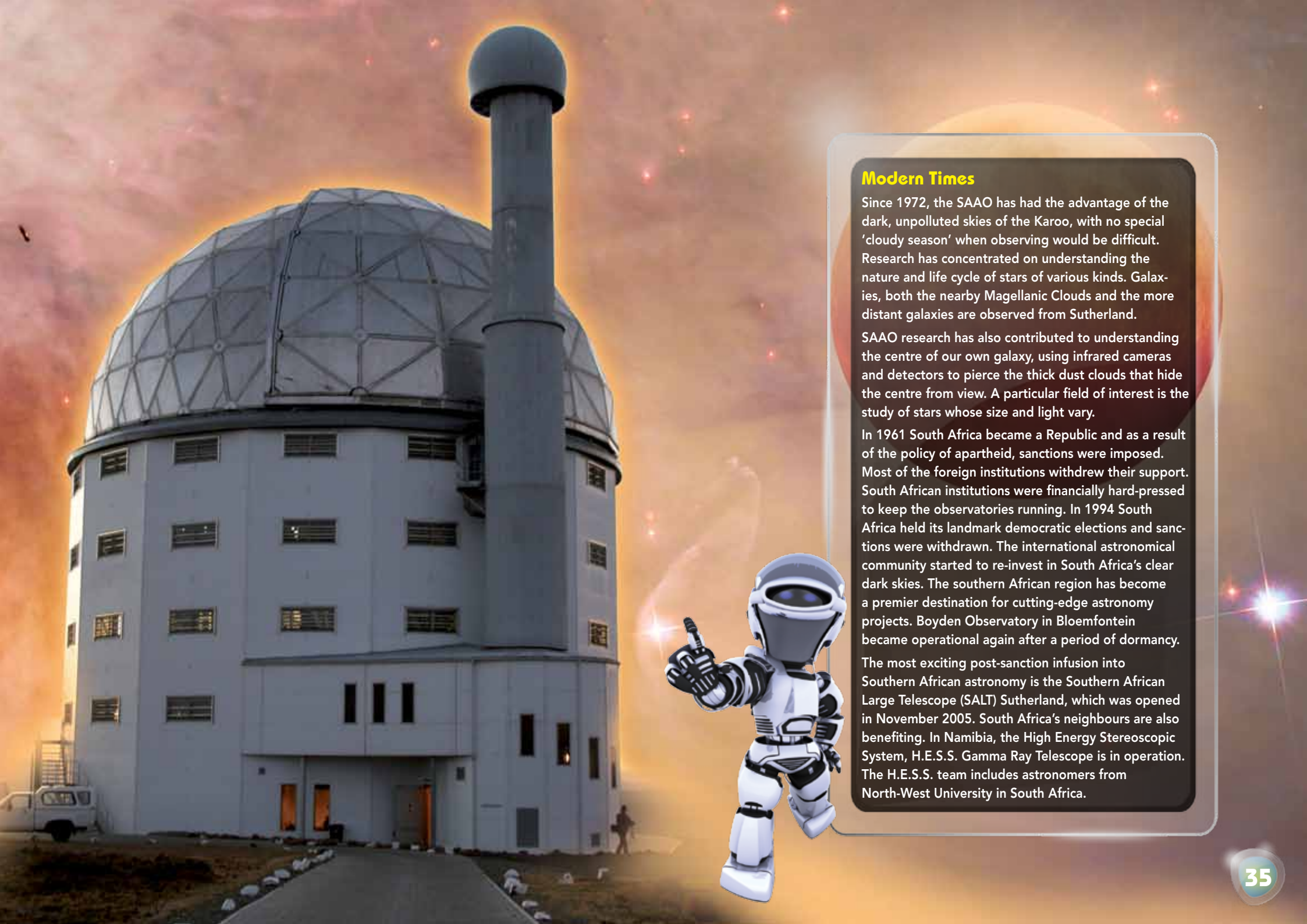
Modern astronomy in South Africa begins with ships. Accurate positions for southern stars were simply not available to navigators and the position of the African coastline was not very well known either. In 1685 a Frenchman, Father Guy Tachard, set up a small temporary observatory in the Cape. He and his assistants discovered that most of the stars shown on their charts of the extreme southern sky did not exist at the marked positions, while many others were omitted altogether. He also estimated (from observations of Jupiter's moons) that Cape Town was nearly 300 kilometres west of its position on his maps of the Earth.

The first dedicated astronomer in South Africa was Nicholas-Louis de la Caille, who spent two years (1751-53) in the Cape. He charted the positions of almost 10 000 stars and measured the shape of the Earth. His geodetic measurements wrongly showed that the Earth was slightly pear-shaped.

In 1820, a permanent observatory was established outside Cape Town. It was headed by a brilliant young Cambridge mathematician, astronomer and clergy-man, the Reverend Fearon Fallows. Two observers were often necessary to get results with the instruments of Fallows' day, but Fallows had great difficulty getting even one reliable assistant. As a result he often observed with his wife, Mary Ann. Her independent discovery of a comet in 1830 places her first on the roll of South African women observers in this field.

The history of the South African astronomy also has roots in other parts of the country. The Natal Observatory was founded in Durban at the time of the 1882 transit of Venus. The observatory was closed in 1911. In 1903 the Transvaal Meteorological Department, from which the Republic Observatory in Johannesburg later developed, was created. The present South African Astronomical Observatory (SAAO) was formed in 1972 by combining the Royal Observatory (Cape Town) with the Republic Observatory (Johannesburg). Its headquarters are in the old Royal Observatory buildings in Cape Town. The three most modern telescopes from the two observatories found a new home in the Karoo just outside the town of Sutherland. In 1974 the Radcliffe Observatory telescope at Pretoria was also moved to the Karoo.

The 0.5-m Telescope at the SAAO near Sutherland with the 0.75-m Telescope in the background.
Photo: Helga Nordhoff



Modern Times

Since 1972, the SAAO has had the advantage of the dark, unpolluted skies of the Karoo, with no special 'cloudy season' when observing would be difficult. Research has concentrated on understanding the nature and life cycle of stars of various kinds. Galaxies, both the nearby Magellanic Clouds and the more distant galaxies are observed from Sutherland.

SAAO research has also contributed to understanding the centre of our own galaxy, using infrared cameras and detectors to pierce the thick dust clouds that hide the centre from view. A particular field of interest is the study of stars whose size and light vary.

In 1961 South Africa became a Republic and as a result of the policy of apartheid, sanctions were imposed. Most of the foreign institutions withdrew their support. South African institutions were financially hard-pressed to keep the observatories running. In 1994 South Africa held its landmark democratic elections and sanctions were withdrawn. The international astronomical community started to re-invest in South Africa's clear dark skies. The southern African region has become a premier destination for cutting-edge astronomy projects. Boyden Observatory in Bloemfontein became operational again after a period of dormancy.

The most exciting post-sanction infusion into Southern African astronomy is the Southern African Large Telescope (SALT) Sutherland, which was opened in November 2005. South Africa's neighbours are also benefiting. In Namibia, the High Energy Stereoscopic System, H.E.S.S. Gamma Ray Telescope is in operation. The H.E.S.S. team includes astronomers from North-West University in South Africa.

Radio Astronomy

In the late 1950s, tracking stations for man-made satellites were erected in South Africa. The Harte-beesthoek Radio Astronomy Observatory (HartRAO) near Krugersdorp had its origins in collaboration with the US Jet Propulsion Laboratory and later NASA. The telescope was originally part of NASA's deep space network of telescopes responsible for supporting a number of early interplanetary and lunar missions. Recently there has been increasing interest in radio astronomy. Until the early developments in the Square Kilometre Array project, HartRAO was the only radio telescope in Africa and is in much demand for international collaboration.

HartRAO

The Square Kilometre Array Radio Telescope

In 2012 South Africa won the major part of the bid to host the Square Kilometre Array (SKA), the largest ever radio telescope. Australia will be hosting the remaining parts of the SKA project. This radio telescope will be able to probe the secrets of the beginning of time.

To help develop the new technologies needed for the SKA, South Africa embarked on the MeerKAT project, a precursor to the eventual SKA. A precursor to MeerKAT itself was the Karoo Array Telescope – being the first 7 MeerKAT radio dishes. It is thus called KAT-7, the seven telescopes each being 12 metres in diameter and built west of Carnarvon in the Northern Cape. This project has been so successful that it is fully booked by local and international astronomers.

An artist's impression of the completed SKA

Geodesy

"Geodesy" means the measurement of the shape of the Earth. Space Geodesy in South Africa is a spinoff of radio astronomy at Hartebeesthoek. It started as part of a NASA programme to measure the present-day movement of the continents. The Hartebeesthoek 26 metre diameter radio telescope took part in this programme, starting in 1986. The telescope, which is attached to bedrock, was found to be moving North-East at 25 millimetres per year. This 1992 result was the first measurement of the motion of the African continent and has been confirmed by many years of measurements since then. As a result of its accuracy, from 1998 its position has been used as the reference point for the survey system of South Africa, used for accurate position measurement. This replaced the old system which dated back to the 1880s and in which the astronomers at the Cape Observatory (now SAAO) had been involved.

The Space Geodesy Programme in South Africa now also operates a NASA Satellite Laser Ranger (SLR), which fires high power laser pulses at satellites. Mirrors on the satellites reflect the light back to the SLR, which measures how long the round trip took. This system can measure the orbits of satellites to an accuracy of a few centimetres. This is so accurate that it even takes into account the effects on the calculations of the speed of light.

In addition, Global Positioning System (GPS) receivers have been set up in several places in South Africa and in other Southern African countries, on Mauritius and Marion Island in the Indian Ocean and at the South African National Antarctic Expedition (SANAE) base in Antarctica, in order to measure their movements. Several GPS receivers are placed alongside tide gauges so that together they can accurately measure the change in sea level caused by global warming.

Solution to the Saturn Word Puzzle


NRF
National Research Foundation
SAASTA
South African Agency for Science and Technology Advancement