South African Astronomical Observatory

ANNUAL REPORT 2018/19

NRF National Research Foundation 1999-2019 20

SAAO South African Astronomical Observatory

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Front Cover: McClean Telescope at SAAO headquarters during open nights.
Credit: Richard Sessions

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Message from the SAAO director

Welcome to the newly resurrected SAAO annual report. We have not published a formal annual report for more than a decade, and never this colourfully, I am sure. There are many reasons to attempt to be more visible and advertise what we do, whether in a glossy print such as this or across various electronic and social media. Recording information that otherwise could easily be lost, events that might be forgotten, is only an immediate reason – impacting the world outside is the more poignant goal.

Our Observatory will turn 200 years in October 2020, and we wish next year to be a year of celebration not only for us but for science in general in South Africa. Science engagement has been added as one of the four pillars of the NRF mandate – science must engage the society if it is to make positive contributions to the actual lives of people and combat the abounding misinformation and erosion of critical and analytical thinking.

We are privileged in astronomy, being involved in something inherently inspiring – and I'm keenly aware how operating on public funding gives us the responsibility to tell a story, to paint a compelling picture of what science really is, and in our case share what we have found out about the amazing universe we live in. We want to tell this story, and we must tell this story, since it is not acceptable to do science in a corner, however excellent it might be.

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Year 2018/2019 in review

Looking back at the April 2018 to March 2019 period, we have clarified the focus of our future science strategy to transient and time-domain astrophysics, galaxy evolution, and exoplanets and solar system studies. One of the main thrusts going forward is our so-called 'Intelligent Observatory' (IO) initiative with a goal to effectively network the many telescopes up in

NRF National Research Foundation 20 1999-2019 | SAAO South African Astronomical Observatory

Sutherland into a single machine, or, dare we say, an 'organism'. It is clear that very rapid time-scale decision making with autonomous systems using a flexible suite of instruments and telescopes is needed to address the challenges of astronomy in the 2020s.

The village of telescopes at Sutherland grew by the commissioning of MeerLICHT, a 0.65-m telescope working, quite uniquely, together with MeerKAT, the radio telescope array, also newly commissioned some 200 km further north. We also entered into agreements to bring two new telescopes to Sutherland in 2020, ATLAS and PRIME, collaborative efforts with the U.S.A. and with Japan, respectively.

One of the significant developments of the period was for SAAO to enter into a new collaborative agreement with our sister organisation SARAO in building new instrumentation for SALT and also contributing to the above-mentioned IO project. Much of the technical work began only in early 2019, so more details will be given in next year's report.

In other NRF inter-facility activities, we have started planning an office building for the SAEON Fynbos node on our premises and discussed tighter collaboration with the technical staff of iThemba LABS.

The SAAO staff continues to publish first-rate research, with more than 100 peer-reviewed publications in the reporting period (the calendar year 2018). Some of these are highlighted in this report, results ranging from studies in the far reaches of our own Solar system, to various stages of stellar evolution, to distant galaxies. SAAO scientists are still heavily involved in hunting for neutron star mergers, i.e., counterparts of gravitational waves, as we were in the landmark international multi-messenger study in 2017.

South African astronomy scored in a big way by winning the bid to host the 2024 International Astronomical Union's General Assembly in Cape Town. It is the first time in its 100-year history that the event will be in Africa. SAAO astronomers played a large role in the bid preparation and are leading the committee going forward. The Office of Astronomy for Development (OAD), which is hosted by SAAO, was also heavily involved, which I am extremely grateful for. The OAD itself received deserved recognition for highlighting the development of astronomy and its socio-economic impact in Africa.

SAAO became a National Heritage Site in December 2018, an exciting development which we hope will help us preserve the history of the area, while at the same time increasing public engagement on the site and continuing to work as a modern research facility.

Staff-wise, we celebrated the 40 remarkable years of Fred Marang working with the Sutherland telescopes, something which was also featured on CNN. On a bitter-sweet note, we bade farewell to Prof. Michael Feast who passed at the age of 92. He was the SAAO Director from 1976 to 1992 and still actively contributed to the life of the Observatory until his last year.

Dear Reader, please enjoy the highlights of the annual report.

Prof. Petri Väisänen

Many thanks to the talented team who put the annual report together, Thabisa Fikelepi, Anja Schröder, Daniel Cunnama, and the designers, GAPdesign.

Message from the Deputy CEO of the National Research Foundation

This year the National Research Foundation celebrates its 20th year. In 2020 the NRF's premier optical and infrared astronomy facility, the South African Astronomical Observatory will celebrate 200 years of astronomy research!

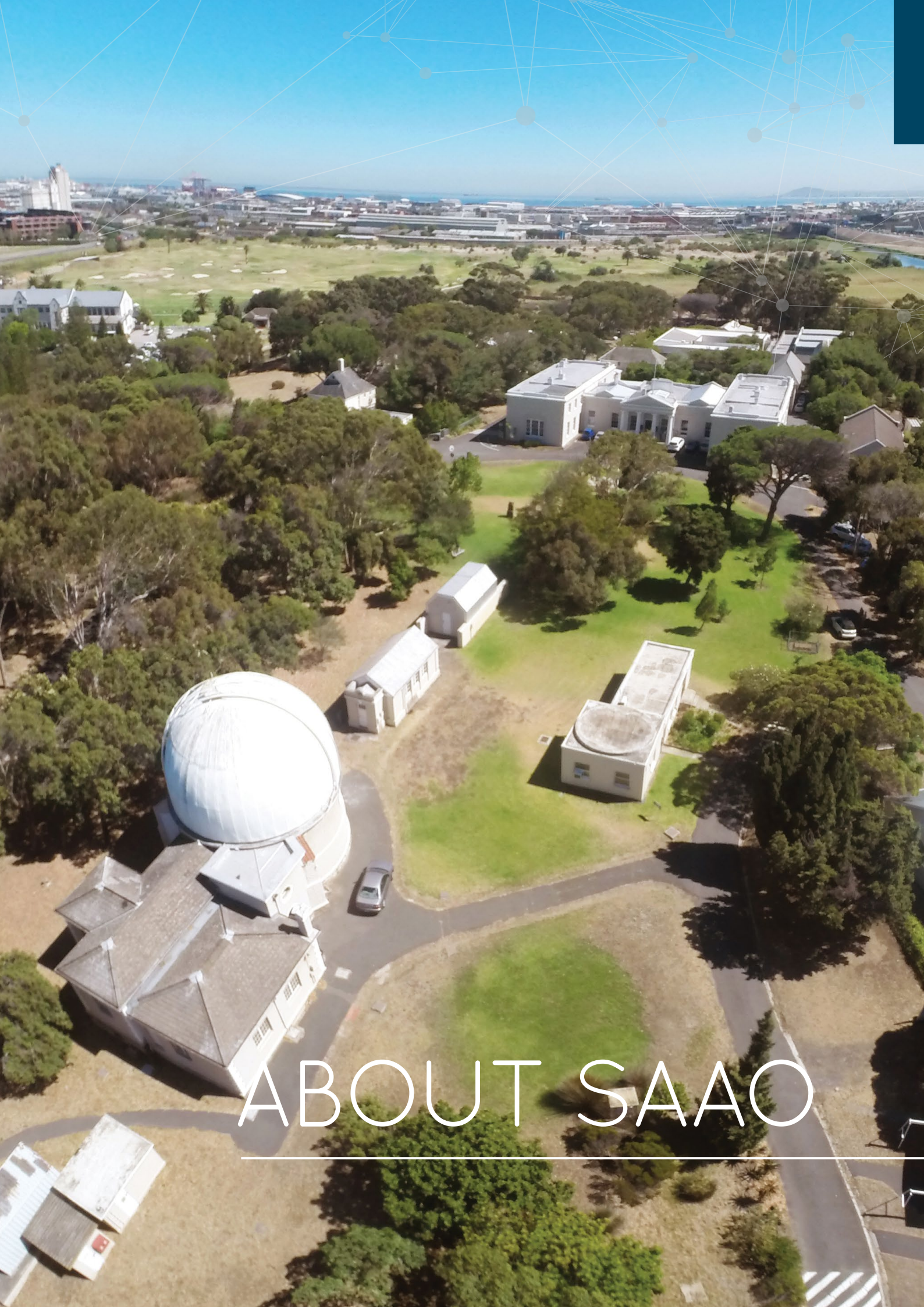
The SAAO has a long and illustrious history of astronomical excellence and that heritage has continued in recent decades, growing into a world-renowned astronomy facility. SAAO continues to lead the way in South African astronomy and there are bold plans for the further advancement of the SAAO as we enter the Fourth Industrial Revolution.

We look forward to many more astronomy highlights in the coming years!

Dr Clifford Nxomani

SAAO continues to lead the way in South African astronomy and there are bold plans for the further advancement of the SAAO as we enter the Fourth Industrial Revolution

National Research Foundation 20 1999-2019



ABOUT SAAO

The South African Astronomical Observatory (SAAO) is a national facility of the National Research Foundation (NRF), which operates under the Department of Science and Innovation (DSI). It is the national centre for optical and infrared astronomy in South Africa. Its primary function is to conduct fundamental research in astronomy and astrophysics. SAAO oversees the Southern African Large Telescope(SALT), located at its site near Sutherland, on behalf of an international consortium and promotes astronomy and astrophysics in Southern Africa.

science & innovation
Department:
Science and Innovation
REPUBLIC OF SOUTH AFRICA

National Research Foundation 1999-2019

SAAO
South African Astronomical Observatory

OFFICE OF ASTRONOMY FOR DEVELOPMENT

SAAO's headquarters is located in the eponymous suburb of Observatory in Cape Town within the Two Rivers Urban Park, at the confluence of the Black and Liesbeek Rivers. Its history dates back to 1820 when the establishment of the observatory was authorised, making it one of the oldest permanent structures in Cape Town. Owing to light and air pollution in the city, research observations take place at SAAO's Sutherland site in the Karoo semi-desert region. Nevertheless, some of the historical telescopes in Cape Town are still used for outreach and public events. Open nights are held every second and fourth Saturday each month and comprise a public lecture, a tour of the SAAO Museum and a stargazing session.
The Cape Town site is also one of the last remaining places close to the city centre where the original ecology of the area is preserved. Its low-lying portions are subject to occasional flooding and support a wide range of bird and animal life as well as a variety of flowering bulbous plants. The grounds mark the northern limit of the Western Leopard Toad (Amietophrynus pantherinus), an endangered species, and it is the only remaining habitat of the rare iris Moraea Aristata.

On a hill-top, 1800 metres above sea level and far from Cape Town's city lights, stand 24 telescopes of various sizes and form

The Office of Astronomy for Development (OAD, hosted by SAAO) is a joint project of the International Astronomical Union (IAU) and the South African National Research Foundation (NRF) with the support of the Department of Science and Innovation (DSI). Since 2013, the OAD has granted over € 700 000 to more than 140 astronomy-for-development projects across the globe. The OAD leverages astronomy, in all its aspects, and is guided by the United Nations 'Sustainable Development Goals' to work towards a vision of "astronomy for a better world".

SAAO's main research telescopes are located at the observing site 15 km from the small Karoo town of Sutherland in the Northern Cape, a 4-hour drive from Cape Town. On a hill-top, 1800 metres above sea level and far from Cape Town's city lights, stand 24 telescopes of various sizes and form, some owned by SAAO and some hosted for international research institutes (see pages 8-11). They give astronomers in South Africa and all over the world access to our exceptionally dark skies. The site is ideally placed in longitude between the other large optical observatories of the southern hemisphere (in Chile and Australia) and allows continuous coverage for time-critical observations.

SAAO Telescopes

SALT*
(Southern African Large Telescope)

9 x 11 m

Spectrographs (low and high resolution), CCD camera, spectro-polarimeter

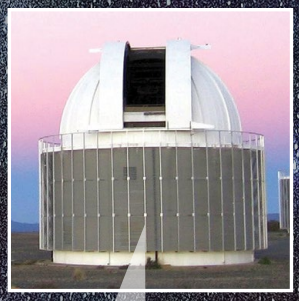
Start of science operations: 2011

Lesedi

1.0 m

CCD cameras, spectrograph coming soon

First light: 2016



1.9-metre

1.9 m

Spectrographs, CCD Cameras, Polarimeter

Start of science operations: 1938-48

ACT (Alan Cousins Telescope)

0.75 m

Photometer

Start of science operations: 1999

1.0-metre

1.0 m

CCD cameras

Start of science operations: 1964

**SALT is an international consortium with SA being the largest shareholder; it is hosted and operated by SAAO*

SAAO Co-hosted Facilities

IRSF (InfraRed Survey Facility)

1.4 m

Nagoya Univ, Kyoto Univ, NAOJ (Japan), and SAAO

IRSF is a fruitful collaboration between Japan and SAAO since 2000 and offers a near-infrared camera (SIRIUS).

MeerLICHT

0.65 m

Six institutes in South Africa, the Netherlands and the United Kingdom

MeerLICHT – Dutch for 'MORE LIGHT' – is fully robotic and aims to provide a simultaneous, optical view of the radio sky as observed by MeerKAT to help identify and classify transient events.

BiSON (Birmingham Solar Oscillations Network)

0.5 m

Birmingham University (UK) and SAAO

BiSON is a cooperative programme between SAAO and Birmingham University, UK, to study the 5-minute oscillations of the Sun. Its Sutherland station is one of six networked solar telescopes spread around the world.

KELT-South (Kilodegree Extremely Little Telescope)

4.2 cm / 7.1 cm, telephoto lenses

Ohio State University, Vanderbilt University, Lehigh University, SAAO

KELT consists of two robotic telescopes: KELT-North in Arizona, USA, and KELT-South at Sutherland. They are conducting a survey for transiting extrasolar planets.

Hosted facilities

KMTNet
(Korea Microlensing Telescope Network)

1.6 m

Korean Astronomy and Space Science Institute (KASI)

KMTNet is a Korean network of three identical 1.6-m telescopes situated in the southern hemisphere (Chile, South Africa, and Australia), conducting a wide-field photometric survey. The network's main scientific goal is to discover earth-mass planets using the gravitational microlensing technique.

LCO
(Las Cumbres Observatory)

3 x 1.0 m and 1 x 0.4 m

Las Cumbres Observatory

The Las Cumbres Observatory is run by a private operating foundation; it consists of a global network of telescopes and operates as a single facility. LCO is used for professional research and citizen investigations. Sutherland is the location of three 1-metre and one 0.4-metre telescopes.

MONET
(MOnitoring NEtwork of Telescopes)

1.2 m

University of Göttingen, Germany

MONET consists of two fully automatic telescopes located at the observatory sites of partner institutions in Texas and South Africa. A large fraction of observing time is available to schools.

Solaris-1 and Solaris-2

2 x 0.5 m

Poland

Solaris is a Polish scientific initiative to open a new frontier in the hunt for extrasolar planets. It consists of a global network of fully autonomous telescopes: two at SAAO and one each in Australia and in Argentina.

OSR
(Optical Space Research)

0.5 m

SANSA, DLR (the German Aerospace Centre)

The OSR laboratory is a space debris tracking telescope (part of the Small Aperture Robotic Telescope Network, or SMARTnet), to enable activation of collision-avoidance measures, to ensure the safe operation of satellites.

MASTER-SAAO
(Mobile Astronomical System of the TElescope-Robots Network)

2 x 0.4 m

MASTER-Net

MASTER-Net is a network of optical transient alert twin-telescopes distributed in longitude over Russia, Argentina and South Africa (MASTER-SAAO). It is a fast survey system, covering more than 2000 square-degrees of sky per night.

ASAS-SN
(All-Sky Automated Survey for SuperNovae)

0.4 m

Las Cumbres Observatory, Ohio State University

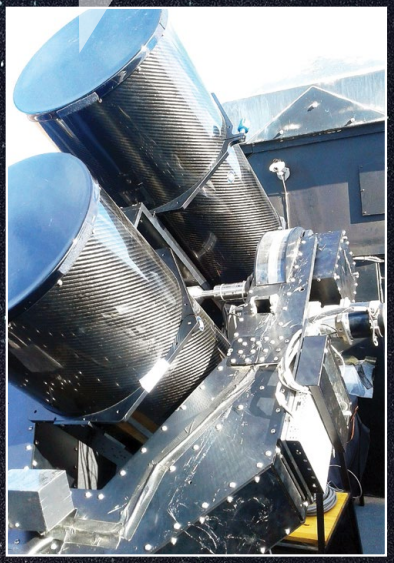
The LCO's Aqawan hut hosts both the ASAS-SN as well ast the 0.4-m LCO telescope. The network comprises five ASAS-SN telescopes.

Xamidimura

2 x 0.4 m

Keele University, UK

Xamidimura (meaning "Eyes of the Lion") is a new installation in the enclosure formerly housing SuperWASP, dedicated to following up eclipsing binary discoveries.

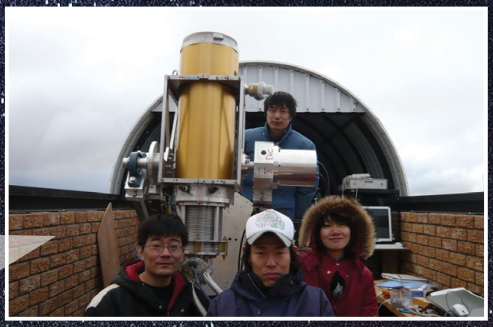


WFTC II (Wide Field Cryogenic Telescope)

0.22 m

Nagoya Univ, Kyoto Univ, NAOJ (Japan)

WFTC II is a special infrared telescope whose interior is under vacuum and cooled to cryogenic temperatures. It has not been used much in recent years. The roll-off roof building was named Semi-hut for the Sumitomo Foundation that supplied funding.



bRing Project (ß Pic b ring)

2 x 2.4 cm f/1.4 wide field lenses

University of Rochester, USA; NASA Jet Propulsion Laboratory; Leiden University, Netherlands

The bRing experiment consists of a twin/two-camera telescope, monitoring the bright star β Pictoris for signs of obscuration from circumplanetary dust associated with the young gas giant exoplanet β Pic b.

Hosted instruments

SAGOS (South African Geodynamic Observatory Sutherland)

German Research Centre for Geosciences (GFZ)

The SAGOS seismograph is a semiconducting gravimeter providing continuous high-resolution monitoring of changes in the Earth's gravity field.

ASTMON

2 fish-eye photo lenses

All-Sky Monitor; used to determine the sky brightness in magnitudes.

SANSA facility

SANSA

The SANSA container comprises several instruments (airglow imager, night-vision video cameras, extremely low-frequency receiver, mesospheric temperature mapper and satellite-based augmentation system receiver) to study the Earth's atmosphere and ionosphere, including research into how sprites are triggered and their effects on the upper atmosphere.

SAAO NEWS

Declaration of the South African Astronomical Observatory as a National Heritage Site

On December 21, 2018, the South African Heritage Resources Agency (SAHRA) officially declared the SAAO site at Cape Town as a National Heritage Site. This is a very exciting development for the Observatory, recognising its incredible achievements and their significance over the past two centuries and ensuring this heritage will be preserved. The declaration was made with the understanding that SAAO remains a working site and that the Heritage status will not curtail its primary function as a world-class observatory.

SAHRA released the following statement along with a statement of significance: "SAHRA identified the site as having qualities so exceptional that it is of special national significance and warrants declaration as a National Heritage Site."

Statement of Significance:

The South African Astronomical Observatory in Cape Town has played a highly significant scientific role over time as the oldest permanent observatory in the Southern Hemisphere. The site offers an overview of the history of astronomy both locally and internationally. It is a "living site" with almost 200 years of history while still retaining its prominence in the international astronomical community.

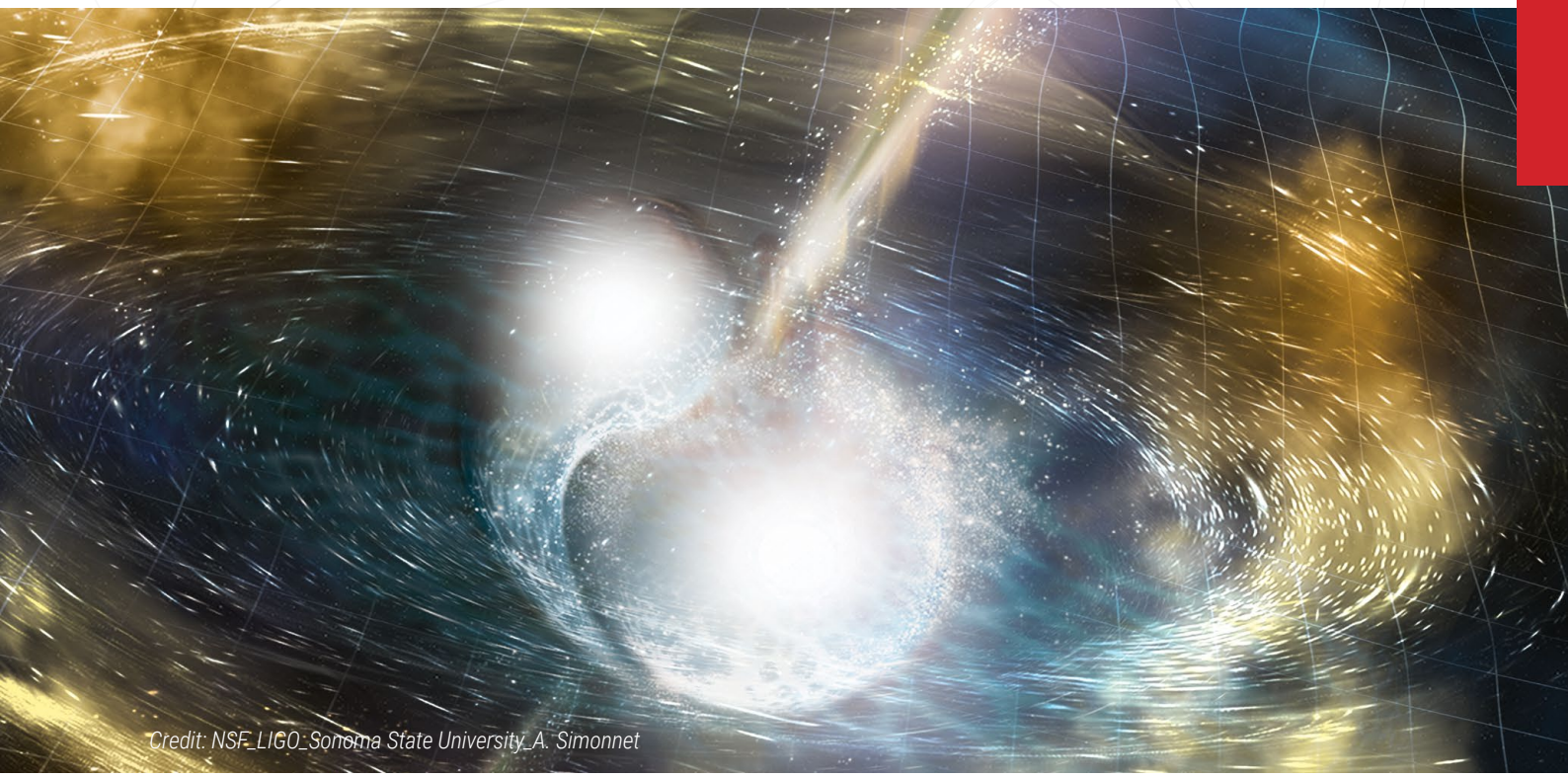
Contributions to astronomy from the site range from some of the first accurate measurements of the distance to a star (Alpha Centauri), first catalogues of the principal southern stars, the first photographic survey of the sky, accurate measurements of the distance to the Sun (a value that became the benchmark to measure all other cosmic distance and represented a paradigm shift in astronomy), development of spectroscopy, remeasurement of Lacaille's Arc of Meridian, establishment of the true shape of the Earth in the Southern hemisphere and the first accurate geodetic surveys of southern Africa.

Architecturally, there are several buildings of historical value and not only reflect the changing architectural styles over the nineteenth century but also have a considerable scientific value due to their contributions to the field of astronomy. The Main Building (a Georgian Building) – designed by the British naval architect, John Rennie, and completed in 1828, the heliograph – the oldest dome on the site and which runs on cannon balls, and the McClean Telescope Building – designed by Herbert Baker.

The range of scientific object related to the observatory as a collection is integral to the scientific value of the site. Some of the instruments within structures have been used with varying degrees of continuity and consistency for over 180 years.

"SAHRA identified the site as having qualities so exceptional that it is of special national significance and warrants declaration as a National Heritage Site."

Credit: Illustrated London News, 21 March 1857/Ian Glass.



Credit: NSF_LIGO_Sonoma State University_A. Simonnet

2018 Nobel Inspired Lecture

The National Research Foundation, in partnership with the Swedish Embassy and with assistance from the Outreach Department in Cape Town, invited guests to attend the 2018 Nobel Inspired lecture "Discovery of Gravitational Waves – What it means for future science" by the Director of SAAO, Prof. Petri Väisänen, on 2 October 2018 at SAAO.

The talk addressed the unprecedented electromagnetic follow-up observations after a neutron star merger event triggered gravitational wave detections*. SALT was one of the first telescopes to obtain spectroscopic data of the light from this explosion. Väisänen further explored the meaning of this new find for the development of Big Science and the future of Multi-Messenger Astronomy in South Africa.

120 members of the public attended the lecture, including members of the local academic community drawn from the three Cape Town based universities UCT, UWC and Stellenbosch University.

From left to right: Mr. Takalani Nemaungani (Acting Chief Director of Astronomy, DST), Dr Molapo Qhobela (CEO, NRF), HE Ms. Cecilia Julin (Ambassador, Embassy of Sweden in Pretoria), Mr. Olof Somell (Curator, Nobel Museum in Sweden), Prof. Petri Väisänen (Director SAAO), Dr Beverley Damonse (Group Executive: Science Engagement and Corporate Relations, NRF).

**SAAO observes the first optical counterpart of a Gravitational Wave source on page 34*

The International Astronomical Union comes to South Africa in 2024

The General Assembly of the IAU to be hosted on African soil for the first time

The 32nd General Assembly of the International Astronomical Union (IAU), taking place in 2024, will be hosted by Cape Town, South Africa. This will be the first time in the 105-year history of the IAU that the triannual General Assembly will be held on the African continent. The award recognises the incredible strides that African astronomy has taken in recent years.

Africa has a long and rich relationship with astronomy, dating back millennia. The world recognized the unique geographical importance of Africa in global astronomy almost two centuries ago with the establishment of the Royal Observatory, Cape of Good Hope, in 1820. Since then, Africa's contributions to global human knowledge have both independently and collaboratively grown from strength to strength. The beginning of the 21st century has seen a renewal of Africa's heritage of astronomical excellence.

XXXII IAU GENERAL ASSEMBLY

CAPE TOWN, SOUTH AFRICA, 2024

South African astronomers celebrating the winning bid at the General Assembly meeting in Vienna in August 2018.

The IAU has held Middle East and Africa Regional IAU Meetings (MEARIM) since 2008. Since the establishment of the IAU's global Office of Astronomy for Development (OAD) in 2011, Africa has become the home of three such regional offices coordinating activities across East Africa from Ethiopia, West Africa from Nigeria, and Southern Africa from Zambia. The mandate of the regional offices is to ensure that the region benefits maximally from the practice of astronomy. The Entoto Observatory in Ethiopia has been operating as an independent research centre since 2013, and in 2017, a 1-m telescope was installed in Burkina Faso as part of the University of Ouagadougou. Africa is also host to the world-renowned HESS telescope in Namibia. The continent is developing the very exciting African Very Long Baseline Interferometry Network (AVN), and a number of countries are rapidly developing their own astronomy programmes and instruments. At the last General Assembly in 2018, Algeria, Ghana, Madagascar, Morocco and Mozambique all became new national members of the IAU. Today, Africa is home to the largest optical telescope in the southern hemisphere (SALT) and one of the largest and most powerful radio telescopes in the world (MeerKAT). It also will play host to a large part of the international Square Kilometre Array (SKA) Project, whose African partnership includes Botswana, Ghana, Kenya, Madagascar, Mauritius, Mozambique, Namibia, South Africa and Zambia. The winning bid is particularly timeous as the SKA telescope is expected to start conducting science observations in the mid-2020s.

The bid had been prepared by the South African astronomical community, in collaboration with the Academy of Science of South Africa (ASSAf) and with strong support from the South African Government and astronomy stakeholders across the African continent. For astronomers, this is like winning the bid to host a Football World Cup or the Olympics. It's time for Africa! We are all excited and look forward to welcoming our colleagues from around the world to the first of hopefully many IAU General Assemblies on African soil. The General Assembly coming to Cape Town in 2024 is an occasion to give voice to Africa in the global astronomical endeavour and will bring attention to the excellent science and education conducted on the continent. It is expected that the opportunity for many African astronomers to take part in one of the world's biggest astronomy meetings will contribute to an enduring legacy of astronomy on the continent.

www.astronomy2024capetown.org

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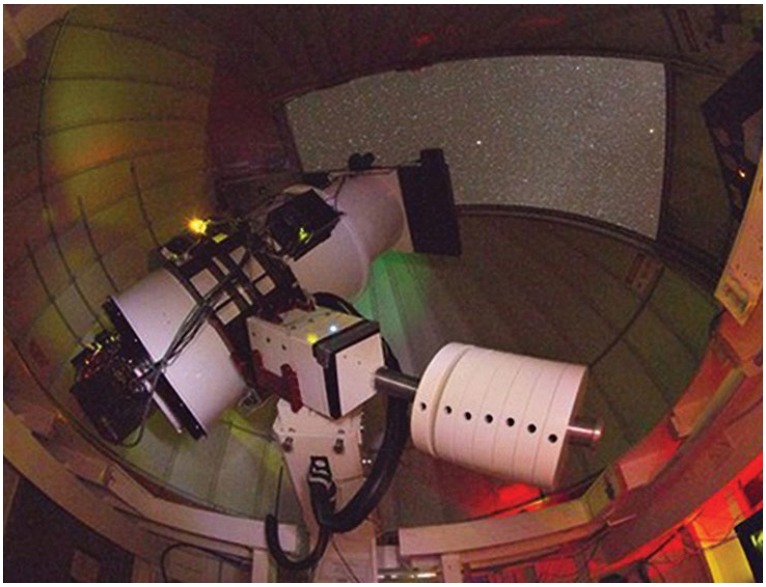
SAAO to contribute to the global effort to detect Near Earth Objects

In the near future, SAAO will play host to the next generation of asteroid-hunting telescopes as part of the NASA funded Asteroid Terrestrial-Impact Last Alert System (ATLAS). On 13 August 2018, NASA confirmed that it will fund two asteroid-hunting observatories in the southern hemisphere at a cost of US$3.8 million. SAAO will host the first site, with the location of the second still to be decided.

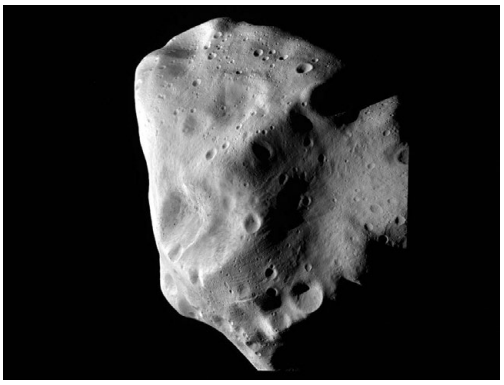
In 2013, NASA announced the Asteroid Grand Challenge (AGC) "to find all asteroid threats to human populations and know what to do about them." The 2013 meteor strike in Chelyabinsk, Russia, in which a 20-m rock exploded mid-air injuring numerous people, was a clear reminder of the busy neighbourhood in which we live and of the destructive potential of asteroids. The ATLAS project was designed to address these concerns and has currently two telescopes operational on the islands of Maui and Hawaii, run by the University of Hawaii. Since start of operations in 2015, ATLAS has discovered over 300 asteroids which pass near the Earth's orbit. However, since these telescopes are located in the northern hemisphere, they are blind to roughly 30% of the southern sky and therefore to any asteroids in that region.

The new telescope in Sutherland will be a fully robotic 50-cm diameter telescope with a 110 MP CCD camera. It will aid in the detection, tracking and characterisation of near-Earth objects (NEOs) and address the current gap in sky coverage by imaging the entire southern sky twice per night. The ATLAS system has software which is optimized to detect fast-moving objects. For example, in early June 2018, the system assisted in providing data on the trajectory of a 1.8-m asteroid called 2018 LA that entered the atmosphere over southern Africa. Using this information, fragments of this asteroid could be found in Botswana. The telescope will be able to detect a 100-m asteroid at a distance of 40 million kilometres (that is, ~ 3 weeks warning) and a 10-m asteroid at a distance of 4 million kilometres (that is, ~2 days warning). Newly discovered NEOs can then be followed up using SALT and other SAAO telescopes to determine the type, rotation rate and other important information.



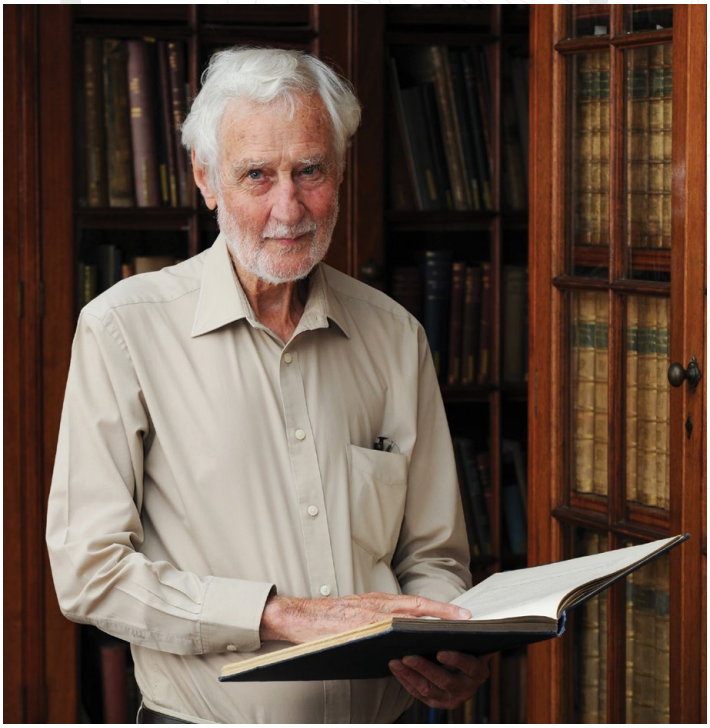
The ATLAS telescope on Haleakala 2018 Credit: Henry Wieland

SAAO's involvement in the ATLAS project offers an excellent opportunity for South African staff, scientists and students to collaborate with NASA and share valuable technology and expertise.



Asteroid Lutetia at closest approach
Credit: ESA 2010 MPS for OSIRIS Team MPS/ UPD/LAM/IAA/RSSD/ INTA/UPM/DASP/IDA

In memoriam Michael Feast



Professor Michael William Feast, a prominent South African astronomer and renowned for his research on the Magellanic Clouds and the structure of the Milky Way, died peacefully on 1 April 2019, aged 92.

Prof. Feast was an Honorary Professor in the Astronomy Department at the University of Cape Town, a former director of SAAO, a Founding Member of the Academy of Science of South Africa, a member of the International Astronomical Union (IAU), an Honorary Fellow of the Royal Astronomical Society, a Fellow of the Royal Society of South Africa and of the South African Institute of Physics (SAIP).

Born and raised in England, as a young boy Michael was removed from his family in the south of England and, with the other village children, was sent to live with host families in Wales for the duration of the war for security reasons.

He came to South Africa in 1952, after a postdoc position in Canada, to work at the Radcliffe Observatory in Pretoria. In 1974, he moved to SAAO in Cape Town, where he served as director from 1976 to 1992. In 1992, he took South African nationality so as to participate fully in the transformation of South Africa. He was passionate about astronomy and continued to do research up to a few months before his death. He read widely, enjoyed talking to students and was an editor of the leading UK astronomy journal, Monthly Notices of the Royal Astronomical Society (MNRAS), from 1993 until 2018.

Using the 1.9-m telescope, first in Pretoria and later at Sutherland, Michael did pioneering work on the Magellanic Clouds, our nearest extragalactic neighbours. His measurements enabled the first estimate of the mass of the Large Magellanic Cloud, which allowed us to understand how it was formed. He also established that the history of the Small Cloud must have been quite different. Many of his papers from the 1950s and 60s continue to be quoted. He established that luminous stars were losing mass and that this set a limit to stellar masses, which is crucial to many things from stellar evolution to the formation of planets.

Being passionate about astronomy, Mike Feast continued to do research up to a few months before his death.

Michael has also made major contributions to the understanding of our own Milky Way Galaxy. A pioneer of multi-wavelength techniques, between 1958 and 1965 he made the first comparison of optical data on young stars with radio measurements of the neutral hydrogen gas. These led him to a new determination of the distance to the Galactic centre and an improved understanding of Galactic rotation. Much more recently, from 1997 to 2015, he combined data from the Hipparcos Satellite with observations from the Hubble Space Telescope and from various SAAO telescopes at Sutherland to investigate the structure of our own Galaxy and to derive a new calibration of the extragalactic distance scale. He has also used SALT to good effect, discovering Cepheid variables at large distances behind the Galactic centre. He published over 300 refereed papers, the first in 1948 and the latest in 2019.

Michael Feast lived a life of integrity and dedication to work, whilst still enjoying the simple pleasures of family dinners, listening to music, reading poetry, and walking deep in conversation with friends.

At the time of his death, Michael was an NRF A1 rated researcher. He had won the Gill Medal of the Astronomical Society of South Africa, the de Beers Gold Medal of the SAIP, and in 2014 was presented with the NRF Lifetime Achievement award.

He was responsible for the development of SAAO as a major national and international facility. Initially a joint enterprise with the British Science Research Council, this developed into an entirely South African operation under his leadership. Telescope time was available to anyone who had a good enough project and this attracted international visitors. This also led to fruitful exchanges of scientific and technical knowledge and was highly stimulating to the SAAO staff, both scientific and technical. He took a strong personal interest in all research done at SAAO and critically read every paper written by a staff member before it was submitted for publication. He encouraged international collaborations and insisted that publications were submitted to first rank international journals.

The Department of Science and Innovation Director-General, Dr Phil Mjwara, said the former director of SAAO will always be remembered for the role he played in promoting astronomy in South Africa. "The work carried out at the SAAO by staff and by astronomers from South African and international universities and institutions during the time of Michael's directorship of the SAAO has not only led to the recognition of South Africa as a major component in world astronomy, it has shown that South Africa's geography, climate and its technical development makes it an excellent place to establish astronomical facilities." He concluded, "It is clear that these factors were significant in convincing international partners to join with South Africa in SALT at the SAAO, Sutherland. That in turn positioned South Africa to bid to host the Square Kilometre Array."

When SAAO and UCT held a conference to celebrate Michael's 90th birthday he insisted that it must not look back, but focus on the future and the wonderful opportunities that astronomy and South Africa offered each other. He lived a life of integrity and dedication to work, whilst still enjoying the simple pleasures of family dinners, listening to music, reading poetry, and walking deep in conversation with friends. He read widely on a broad range of subjects, especially history, art, music, philosophy and religion. He was an Anglican and was especially interested in what lay beyond and outside of the concepts of space and time as we know them. He was a source of wisdom and good council to many who loved him, and an inspiration and help too many who worked with him. His is a life worth celebrating in so many ways.

SCIENCE HIGHLIGHTS

SAAO contributes to the exploration of MU69

On the 1st of January 2019, NASA's New Horizon's spacecraft performed a very exciting fly-by of the most distant object ever explored by a spacecraft: 2014 MU69, nicknamed Ultima Thule. MU69 is located in the Kuiper belt, the icy disc in the outer Solar system that contains leftover material from the formation of the Solar system 4.5 billion years ago. This fly-by presented a rare opportunity to learn more about the remote objects in our outer solar system and how they may have been formed. In preparation, and to learn as much as possible about this object, astronomers at SAAO and around the world have performed Earth-based observations, starting in 2017.

After the New Horizons spacecraft visited Pluto in 2015, scientists re-directed the spacecraft to explore an even more distant object of the Solar system. The choice had fallen on 2014 MU69, a body around 30 km in size located in the outer reaches of our Solar system which had been found by the Hubble Space Telescope in 2014. The aim of the new mission was to learn about its surface composition, its structure, and whether it hosts moonlets, a coma or rings.

Preparatory observations for the MU69 mission began long before the 2019 fly-by: Astronomers, using occultation observations in 2017 and 2018 (Figure 2), learned a fair amount about MU69, like its elongated shape and a more accurate size. Eliot Young from Southwest Research Institute in the USA and his team (including SAAO astronomers) report in their publication on results obtained from the three 2017 occultation observations regarding the possible presence of rings around MU69: on 3 June from SAAO and Argentina, on 10 June from the airborne observatory SOFIA, and on 17 July from Argentina. A ring – or any debris in the vicinity of MU69 – would modulate the way the light of the background stars was blocked (Figure 3). By comparing predicted light curves to the observed dimming of the background stars captured during MU69's occultations, the authors concluded that rings with radii up to 1000 km and radial widths of 720 m were inconsistent with the occultation light curves. The Hubble Space Telescope's occultation observations obtained on 17 July 2017 excluded also any rings larger than this. And indeed, the newly obtained low-resolution images from New Horizons's fly-by in January 2019 do not show any rings.

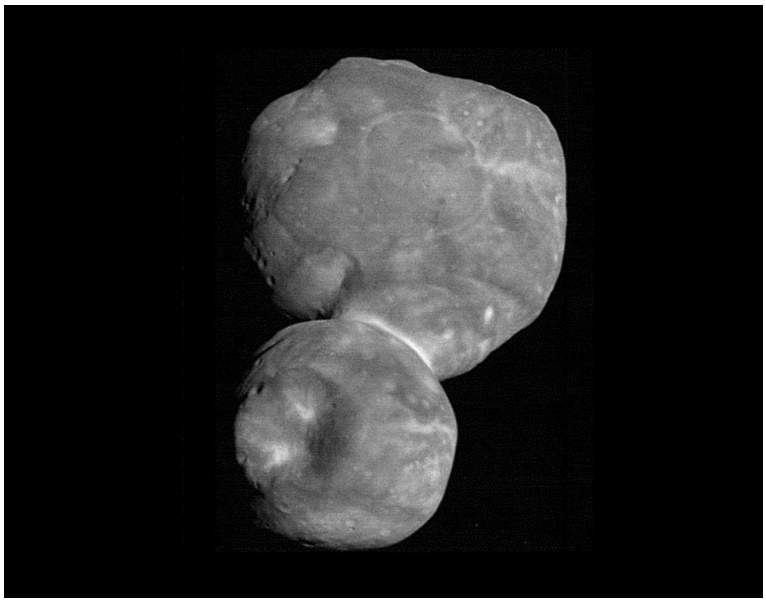


Fig. 1: MU69 as seen by the New Horizons spacecraft. Taken at 5:01 UT on 1 January 2019, just 30 minutes before closest approach, from a distance of 28,000 kilometres. The original scale is of 140 metres per pixel. *Credit: NASA/Johns Hopkins University Applied Physics Laboratory/ Southwest Research Institute*

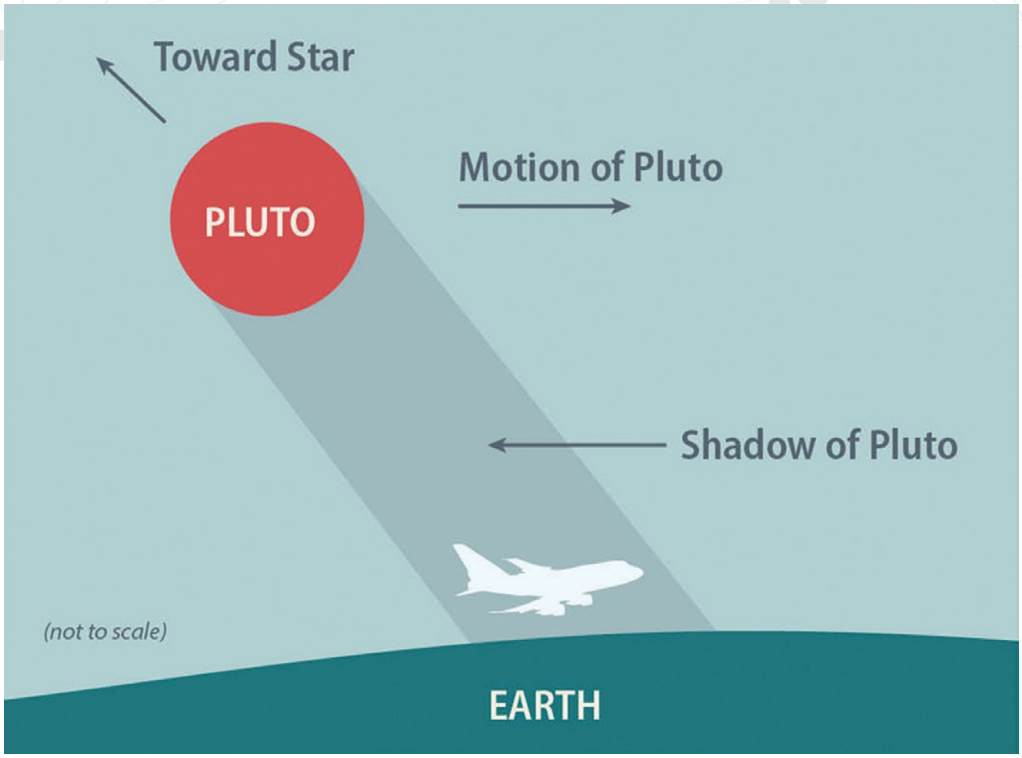


Fig. 2: An occultation observation is performed as the object in question, in this case 2014 MU69, moves in front of a background star, briefly blocking the star's light. Such an occultation can be observed from Earth with carefully placed lines of ground telescopes or with the airborne observatory SOFIA.
Credit: NASA

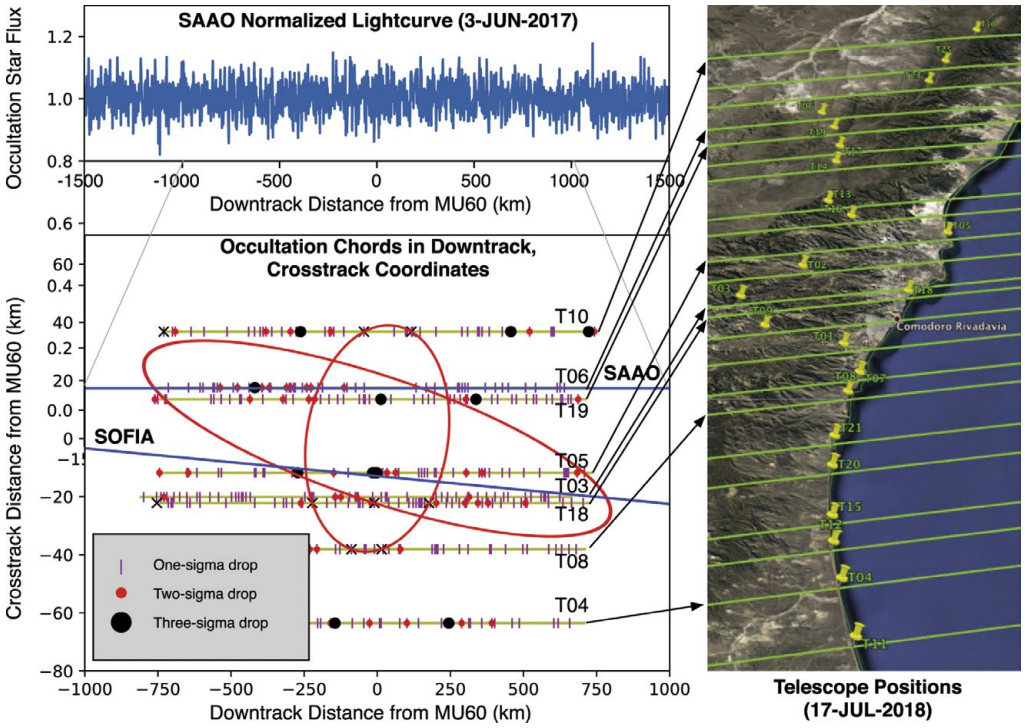


Fig. 3: An example of candidate rings (red ellipses) plotted over a subset of occultation chords from the 2018 July 17 occultation (yellow lines and the map in the right panel). These ellipses cross the portable telescope chords (labeled T10, T06, ..., T04) at locations corresponding to lightcurve low points (with 1σ, 2σ and 3σ marked). Note that the candidate rings shown here do not cross the SAAO lightcurve (upper panel) at low points and are not viable ring candidates that are expected to be seen at MU69. The SAAO lightcurve has a high signal–to–noise ratio of 18.9 per 0.1 s integration.

Young, E.F. , et al., 2018/12, Res. Notes AAS 2, 224: Limits on a Ring System at 2014 MU69 from Recent Stellar Occultations.
Young, E.F. , et al., 2018/04, in EGU General Assembly Conference Abstracts, 20, 18286: Advance knowledge of New Horizons target 2014 MU69 from stellar occultations

Dodging Asteroids

On a regular basis, various space debris, including asteroids, comes close to or impacts the Earth. For example, in October 2017 asteroid 2012 TC4 passed by the Earth approximately 1/8th the distance between us and the moon. While this event did not present a threat (there was no impact and 2012 TC4 was only about 10 metres in diameter so would have burnt up in the atmosphere if it had entered), questions arise as to how to deal with asteroids that are more menacing and pose a risk of great harm. Nicolas Erasmus, an astronomer at SAAO, is co-author of a publication that tries to address this problem.

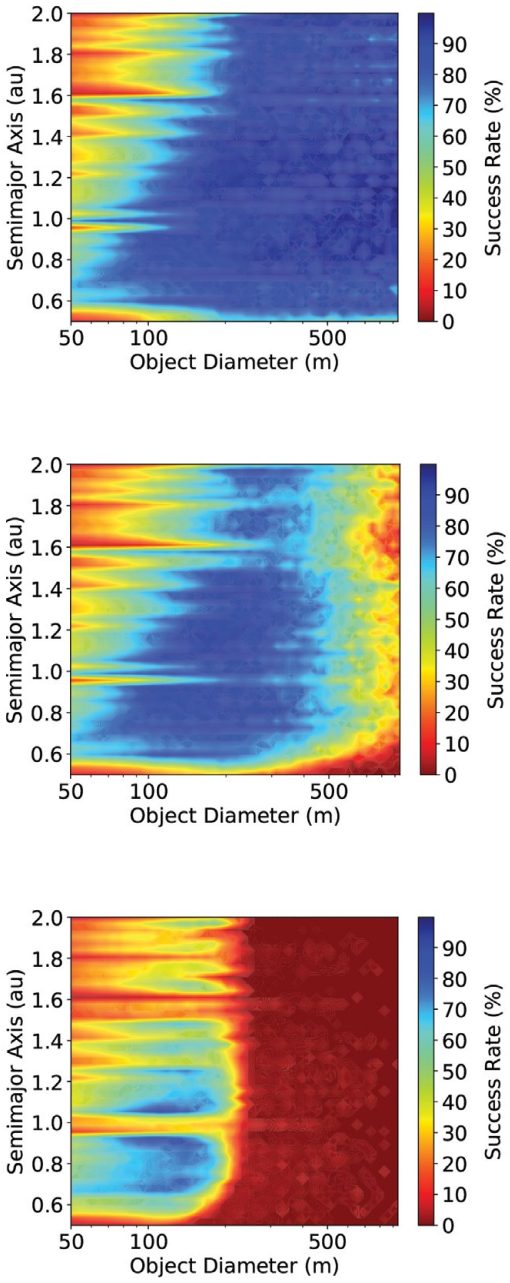
In July 2016, Erasmus attended the Frontier Development Lab hosted by NASA's Ames Research Center and SETI in Mountain View, California. The six-week workshop brought together planetary scientists and machine-learning experts to tackle various challenges that involve asteroids. Erasmus and three fellow team members were asked to address the following dilemma: "Could mankind deflect a hazardous asteroid on a crash course with Earth and if so, which method would give us the best chance?" To answer this, the team worked together to create a machine-learning algorithm called the "Deflector Selector" which can be used to study a given population of potentially hazardous objects and then to determine which technology has the best chance of deflecting them from Earth's path.

To train the algorithm, a simulation of millions of hypothetical asteroids with the potential to hit the Earth was created. For each hypothetical impact, they simulated how far in advance of the collision it could be detected and the velocity change to the asteroid which would be required to avoid the collision with Earth. With the aid of this information, the team reviewed the capability of three technologies to induce this velocity change: a nuclear detonation, a kinetic impactor, and a gravity tractor. The technologies each work differently and present different challenges. Nuclear detonations release an explosive force that can impart momentum which, while effective, carries the dangers associated with launching nuclear warheads into space. The somewhat less effective kinetic impactor causes a change

Artist's impression of an asteroid being blown apart.
Credit: NASA/JPL-Caltech

in momentum by crashing a spacecraft into the asteroid and is technologically the easiest method. Gravity tractors are more subtle and involve hovering a spacecraft near an asteroid, allowing its gravitational pull to nudge the asteroid in a different direction. The latter two technologies currently offer less potent results but have more predictable outcomes. Their effectiveness can also be enhanced by earlier detection and therefore by longer lead times.

Though it takes a long time to generate the training data and to train the algorithm, the benefit of using a machine learning algorithm is that it can provide clear answers extremely quickly when given a new, unknown impact scenario which mankind might one day have to face.



Summaries of deflection simulations as a function of diameter and semi-major axis. (Top) nuclear explosion, (middle) kinetic impactor, and (bottom) gravity tractor. Colours indicate the percentage of successful deflections where blue stands for high success.

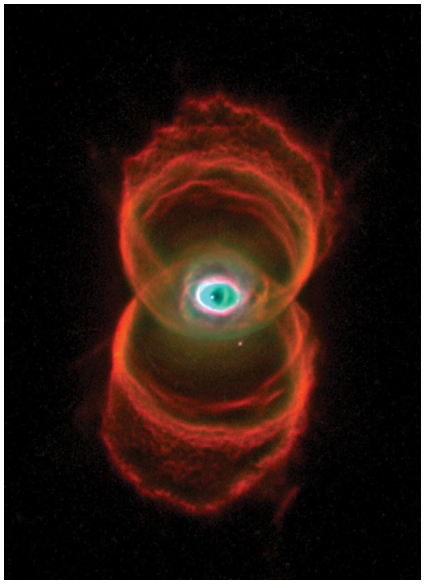
Nesvold, E. R., et al., 2018/05, Acta Astronomica 146, 33: The Deflector Selector: A machine learning framework for prioritizing hazardous object deflection technology development

SALT sees double in the Hourglass Nebula

The Southern African Large Telescope (SALT), SAAO's largest telescope at Sutherland, discovered a binary star system in the Hourglass Nebula, one of the most famous nebulae captured by the Hubble Space Telescope. The Hourglass Nebula consists of two hourglass-shaped lobes of gas and what appears to be an eye staring right back at us. Shells of gas form the eye surrounding the hot central star that illuminates the nebula like a neon sign. Astronomers have long suspected the planetary nebula to be formed by two interacting stars in a binary system, but until now no one could prove it.

An international team of astronomers, led by SALT Astronomer Brent Miszalski at SAAO, used SALT to peer into the "sparkle" of the eye of the Hourglass Nebula – its central star. A total of 26 SALT measurements were taken that detected the small movements of the central star towards or away from us caused by the gravity of a second companion star. This Doppler or "wobble" method, that can also be used to find planets around other stars, revealed a hidden companion orbiting the central star every 18.15 days. Rajeev Manick, PhD student at The Katholieke Universiteit Leuven in Belgium, analysed the SALT measurements and found that the companion must be a small, cool star about 5 times lighter than the Sun. Another surprise came with the binary – the relatively wide separation between the two stars is remarkable. While previous authors have suggested that a nova explosion could explain many aspects of the Hourglass Nebula, this

In the so-called common envelope stage, the cooler star spirals into the atmosphere of its larger companion and ejects the shared atmosphere.



The Hourglass Nebula as viewed by the Hubble Space Telescope in the light of ionized nitrogen (represented by red), hydrogen (green), and doubly-ionized oxygen (blue).
Credit: R. Sahai and J. Trauger (JPL), the WFPC2 science team, and NASA/ESA

The new SALT discovery may help astronomers understand how a wide variety of other hourglass-shaped or butterfly-shaped nebulae form. The picture shows several examples of such nebulae captured by the Hubble Space Telescope, with the Hourglass Nebula visible at the lower left corner.
Credit: ESA/Hubble

Miszalski, B., et al., 2018/06, PASA 35, 27: SALT HRS Discovery of the Binary Nucleus of the Etched Hourglass Nebula MyCn 18

new study discovered that the stars were too far apart for this to have ever been possible. Instead, the orbital period of the binary system indicates that the Hourglass Nebula formed through an interaction that many close binary stars experience – a so-called common-envelope stage. In this scenario, the cooler star spirals into the atmosphere of its larger companion and ejects the shared atmosphere which we now see as the nebula. The Hourglass Nebula is one of very few such examples to show an orbital period above 10 days, which helps to improve our understanding of this brief phase that many types of binary stars experience during their lifetime.

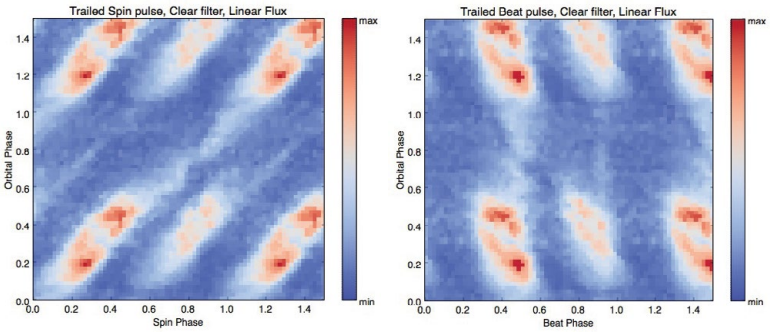
While astronomers still do not quite understand how hourglass-shaped nebulae form, the discovery of a binary in the Hourglass Nebula considerably strengthens the long suspected, but difficult to prove, connection between binary stars and hourglass-shaped nebulae. A famous example is the nebular remnant of Supernova 1987A that is often compared against the Hourglass Nebula because of its very similar shape. It is thought to have resulted from the merger of two massive stars before the supernova event. This process shares similarities with that which formed the Hourglass Nebula, hinting at some shared physics resulting in two of the most unusual nebulae in the sky.

SAAO observes the White Dwarf pulsar in AR Scorpii

When white dwarfs are in close orbits with less dense stars, they can strip material from their companions, and the resulting mass transfer can generate atomic line and X-ray emission as well as near- and mid-infrared radiation if the white dwarf is magnetic. However, even in binaries, white dwarfs are rarely detected at far-infrared or radio frequencies.

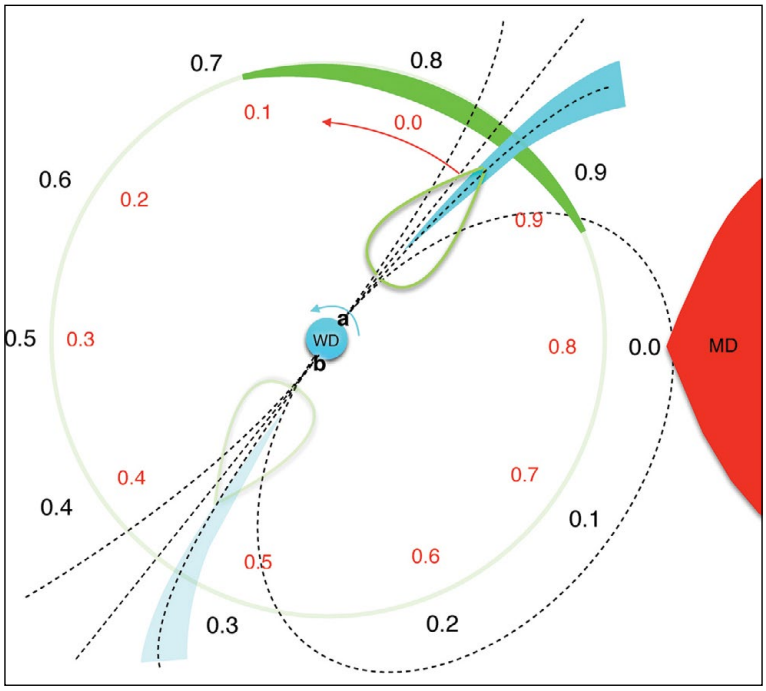
In 2016, a white dwarf / cool star binary that emits from X-ray to radio wavelengths had been discovered. The star, AR Scorpii (or AR Sco), was classified in the early 1970s as a delta-Scuti star, which is a common variety of periodic variable stars. However, the new observations revealed a 3.56-hour-period close binary, pulsing in brightness on a period of 1.97 minutes. The pulses are so intense that AR Sco's optical flux can increase by a factor of four within 30 seconds, and they are also detectable at radio frequencies, the first such detection for any white dwarf system.

AR Sco's broad-band spectrum is characteristic of synchrotron radiation, requiring relativistic electrons. The optical pulses are also strongly linearly polarized, peaking at ~40%. Detailed inspection of the morphology of the polarimetry reveals complexities (see figures next page) that vary on the spin, beat and orbital frequencies. In contrast, VLA time-resolved observations over one orbit show that the polarization is circular, peaking at 30%. Furthermore, it was also detected as a Fermi γ-ray source. Since its discovery, there has been a flurry of follow-up observations and theoretical publications aiming to improve our understanding of this object. Among these are models involving dipole radiation from a strong magnetic field, particle acceleration due to strong electric fields, electrons fed from the secondary star's corona spiralling to magnetic mirror points of the white dwarf and bow shock models.



Evolution of the linear polarized flux beat pulse (left) and spin pulse (right) as a function of orbital phase. In both cases the pulse profiles show complexities that show orbital, spin and beat dependencies as well as "doubling" of the most prominent features.

SAAO astronomers Stephen Potter and David Buckley report on detailed optical photometric and photo-polarimetric observations of AR Sco using SAAO's 1.9-m telescope. Their extensive dataset reveals that the polarized emission is remarkably stable and repeatable with spin, beat and orbital modulations. This enabled the authors to construct a simple geometrical model which assumes that all of the optically polarized emission emanates from two diametrically opposed synchrotron emission regions on the white dwarf's magnetosphere. They suggest that the observed polarimetric modulations occur as a result of an enhanced injection of relativistic electrons into the magnetosphere of the white dwarf as it sweeps past the M-dwarf. This leads to an increase in synchrotron emission as the injected electrons accelerate towards each magnetic mirror point close to the magnetic poles of the white dwarf. Previous conclusions that argued that the observed strong optical beat modulations require the optical polarization to arise predominantly from or near the M-dwarf are inconsistent with the observations.



Schematic of the AR Sco system (not to scale). Black digits: orbital phases indicate the direction to the observer. Red digits: beat phases indicate the angle of the magnetic pole associated with the brighter synchrotron emission region with respect to the M-dwarf. Dashed lines: magnetic field lines from close to the two magnetic poles. Thickening of the green circle: the beat-phase range in which synchrotron emission is intensified. Cyan region: the region where relativistic electrons are nearing a magnetic mirror point giving rise to beamed synchrotron emission (green lobes). Pulses from the fainter synchrotron emission region will also increase in intensity as the associated magnetic pole sweeps through the green region. The green circle is fixed and rotates with the binary frame.

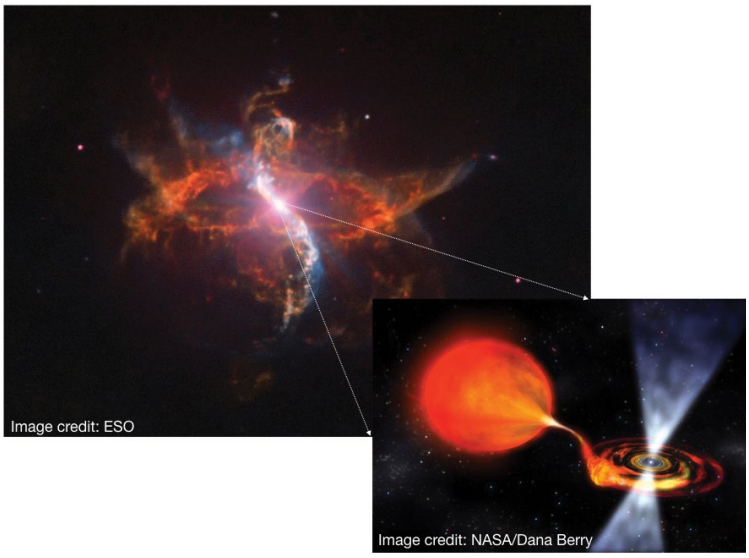
Potter, S.B. & Buckley. D.A.H., 2018/07, MNRAS 478, 78: A reevaluation of the proposed spin-down of the white dwarf pulsar in AR Scorpii
Potter, S.B. & Buckley. D.A.H., 2018/07, MNRAS 481, 2384: Time series photopolarimetry and modelling of the white dwarf pulsar in AR Scorpii

The CO envelope of the symbiotic star R Aquarii as seen by ALMA

R Aquarii (or R Aqr) is a binary star system consisting of an M-type asymptotic giant branch (AGB) star and a white dwarf at a separation of 45 milliarcseconds, equivalent to about 10 AU at the distance of the star (218 pc). R Aqr is an example of a symbiotic binary where the white dwarf is sufficiently close and massive that it can capture material that is lost from the red giant. Some of this captured material is then ejected from the white dwarf in the form of powerful jets. In case of R Aqr, three major components make up the emitted light: cool radiation from the red giant, energetic radiation from the hot white dwarf, and radiation from the excited nebula surrounding the system.

Sofia Ramstedt from the Uppsala University in Sweden, together with Shazrene Mohamed from SAAO and their Swedish collaborators, decided to use the Atacama Large Millimeter/sub-millimeter Array (ALMA) in Chile to investigate the dependence of the wind shaping on the binary separation of symbiotic stars and to provide constraints for hydrodynamical binary interaction models. They selected four binary stars, covering a range in separations and wind properties. R Aqr is particularly interesting as the source with the smallest separation and having a complex circumstellar environment that is strongly affected by the interaction between the two stars and by the high-energy radiation resulting from this interaction and from the hot white dwarf companion.

The authors imaged the innermost molecular envelope of the system using the CO(J = 3→2) line emission at 0.5" spatial resolution.



The CO envelope around the binary pair is marginally resolved, showing a rather complex and aspherical distribution. They find that the outer radius of the CO-emitting region is about a factor of 10 larger than previously thought. This implies an average mass-loss rate during the past 100 yr of $\dot{M} \approx 2\times10^{-7}$ $M_{\odot}$/yr which is a factor of 45 less than previous estimates. The data support the assumption that the mass-loss rate from the red giant star strongly varies and is focused on the orbital plane. Higher resolution observations are needed to improve the understanding of the production of jets and the exchange of mass in these types of systems.

ESO's Very Large Telescope imaged R Aqr (left), showing the nebulosity surrounding the binary star (see artist's impression, right) and the revolving jet. The nebula is the likely result of a violent nova 250 years ago.
Credit: ESO and NASA/ Dana Berry

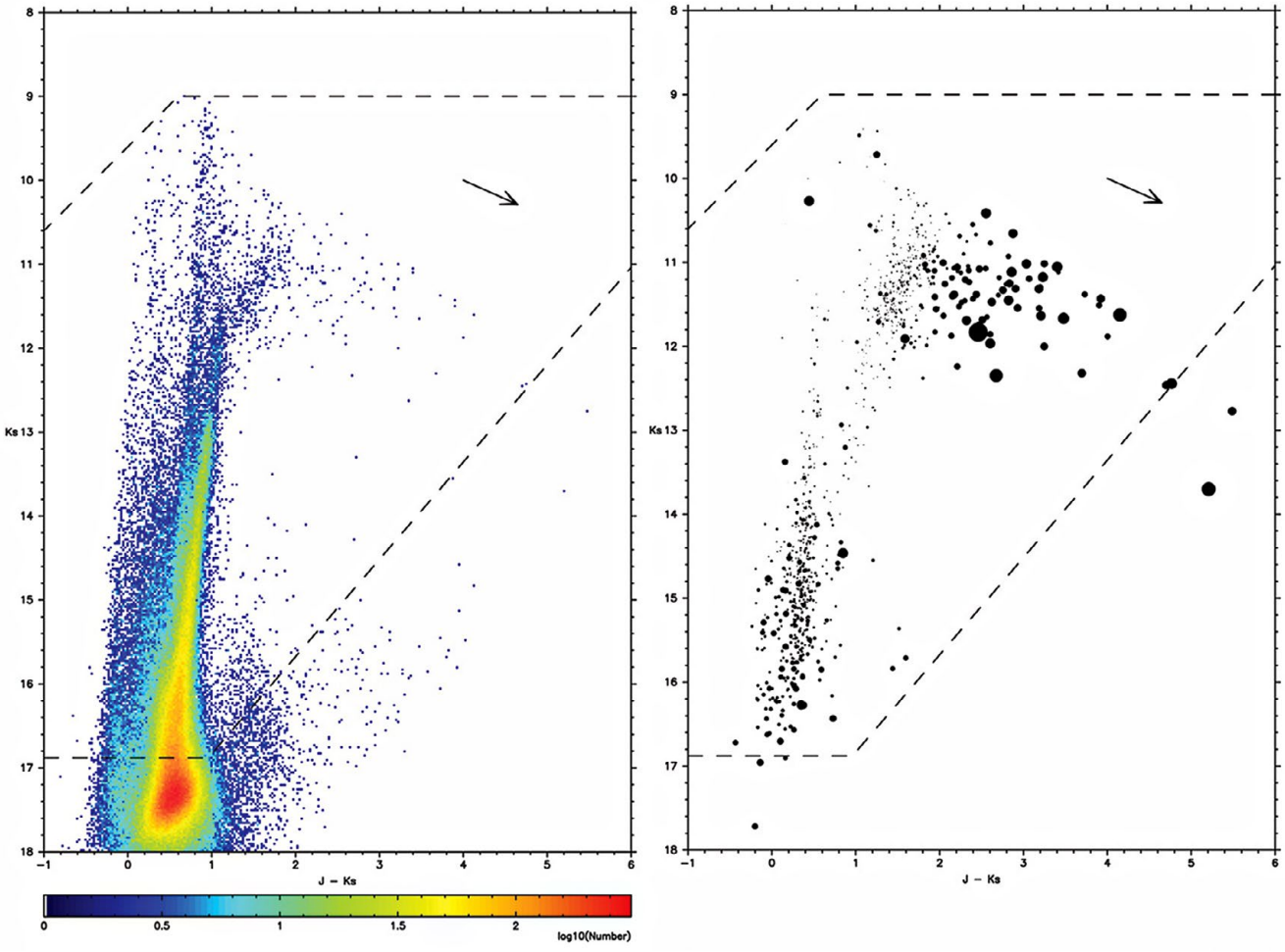
Ramstedt, S., et al., 2018/08, A&A 616, 61: CO envelope of the symbiotic star R Aquarii seen by ALMA

Seventeen years in the life of SMC's variable stars

A very long-term near-infrared variable star survey towards the Large and Small Magellanic Clouds (LMC and SMC) is being carried out using the 1.4-m IRSF. This project was initiated in December 2000 in the LMC and in July 2001 in the SMC. Since then an area of 3 square degrees along the bar of the LMC and an area of one square degree in the central part of the SMC have been repeatedly observed. The survey is ongoing, but the results obtained with data taken until December 2017 were published by Yoshifusa Ita (Tohoku University, Japan) and his collaborators from Japan and SAAO.

Covering a time span of more than 15 years, the two survey areas were observed at least one hundred times. This is the first survey that provides NIR time-series data with such a long-time baseline and on such a large scale. The publication includes a point source photometric catalogue, a variable source catalogue, and time-series data for the SMC.

Left: a colour-magnitude diagram of all sources detected by the authors in the SMC survey area. Right: similar to the left, but showing variability: the size of a point is proportional to the standard deviation of the J magnitude; the dashed line shows the 90% completeness limit and the reddening vector represents $E_{B-V} = 1.0$.



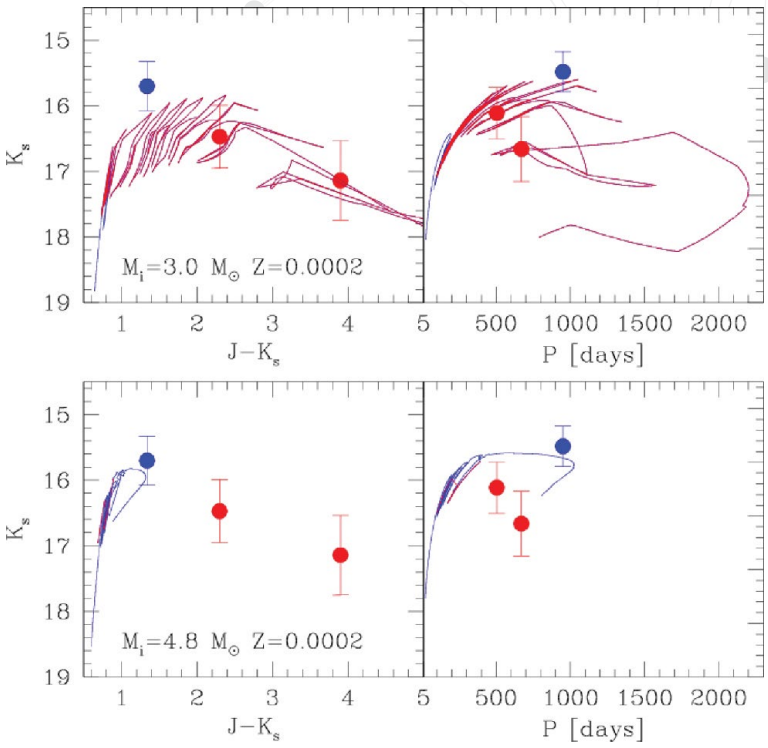
Ita, Y., et al., 2018/12, MNRAS 481, 4206: A near-infrared variable star survey in the Magellanic Clouds: the Small Magellanic Cloud data

Asymptotic Giant Branch Variables

Continuing their studies of asymptotic giant branch (AGB) variables in Local Group galaxies, Patricia Whitelock from SAAO and her South African-Italian team report on near-infrared photometry for the Sagittarius dwarf irregular galaxy (Sgr dIG, a very metal-deficient galaxy about 3.4 million light-years away), obtained over 3.5 years with the 1.4-m IRSF telescope. They identified three large-amplitude asymptotic giant branch variables. One of them, dubbed V1, is an oxygen-rich star with a pulsation period of 950 days which was until recently undergoing hot bottom burning. It has a bolometric magnitude of M_{bol} ~ -6.7.

Rather little is known about AGB stars in such metal deficient galaxies, but it is surprising to find a variable of this sort in Sgr dIG, given their rarity in other dwarf irregulars. Despite its long period the star is relatively blue and is fainter (at wavelengths shorter than 4.5μm) than anticipated from period-luminosity relations that describe hot-bottom-burning stars. A comparison with models suggests it had a main-sequence mass ~5 $M_\odot$ and is now near the end of its asymptotic giant branch evolution. The other two periodic variables are carbon stars with periods of 670 and 503 days. They are very similar to other such stars found on the asymptotic giant branch of metal-deficient Local Group galaxies and a comparison with models suggests main-sequence masses around 3 $M_\odot$. A comparison of the number of asymptotic giant branch variables in Sgr dIG to those in NGC 6822 and IC 1613 suggests that the differences may be due to the high specific star formation rate and low metallicity of Sgr dIG.

An additional interest of this study is to establish the viability of Mira variables for distance scale studies; hence the authors compare the detection likelihood of Mira variables and of Cepheid variables. With the IRSF, any large amplitude variable with mean K < 17.2 could be detected. A Cepheid with K = 17.2 would have a period of 50 d and a mass about 9 $M_\odot$ which is considerably larger than the estimate for V1. Such long-period Cepheids are rare; there are only two in NGC 6822 with P > 50 d and none in IC 1613, and both these galaxies are significantly more massive than Sgr dIG. Sgr dIG could well contain Cepheids with periods of a few days, but these are too faint to detect with a 1.4-m telescope (a Cepheid with P = 3 d would have K ~ 21.5.). This illustrates the potential of Mira variables in the era of the James Webb Space Telescope (JWST) and of large ground-based telescopes optimized at infrared wavelengths. Miras will be easily detected where individual stars of low or intermediate mass can be resolved. They should prove very useful probes of stellar populations as well as standard candles for the distance scale.



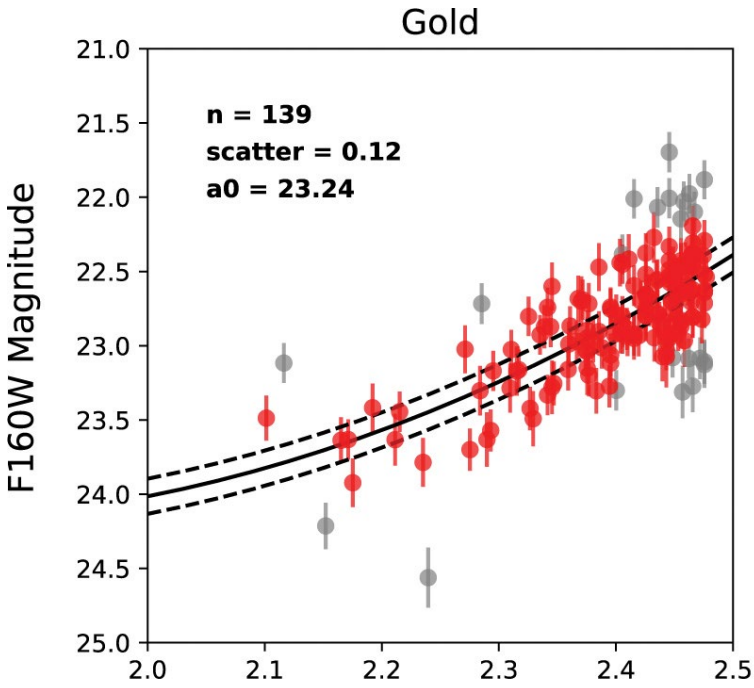
Colour–magnitude and period–luminosity diagrams for the detected variables (C-stars in red and O-rich stars in blue). Dots represent the stars and error bars show the variability range. AGB evolutionary tracks are shown for two choices of the initial mass as indicated, with metallicity Z = 0.0002. Stages characterized by surface C/O < 1 and C/O > 1 are coloured in blue and red, respectively.

Whitelock, P.A., et al., 2018/01, MNRAS 473, 173: A remarkable oxygen-rich asymptotic giant branch variable in the Sagittarius Dwarf Irregular Galaxy

Mira variables: An anchor for a new distance ladder

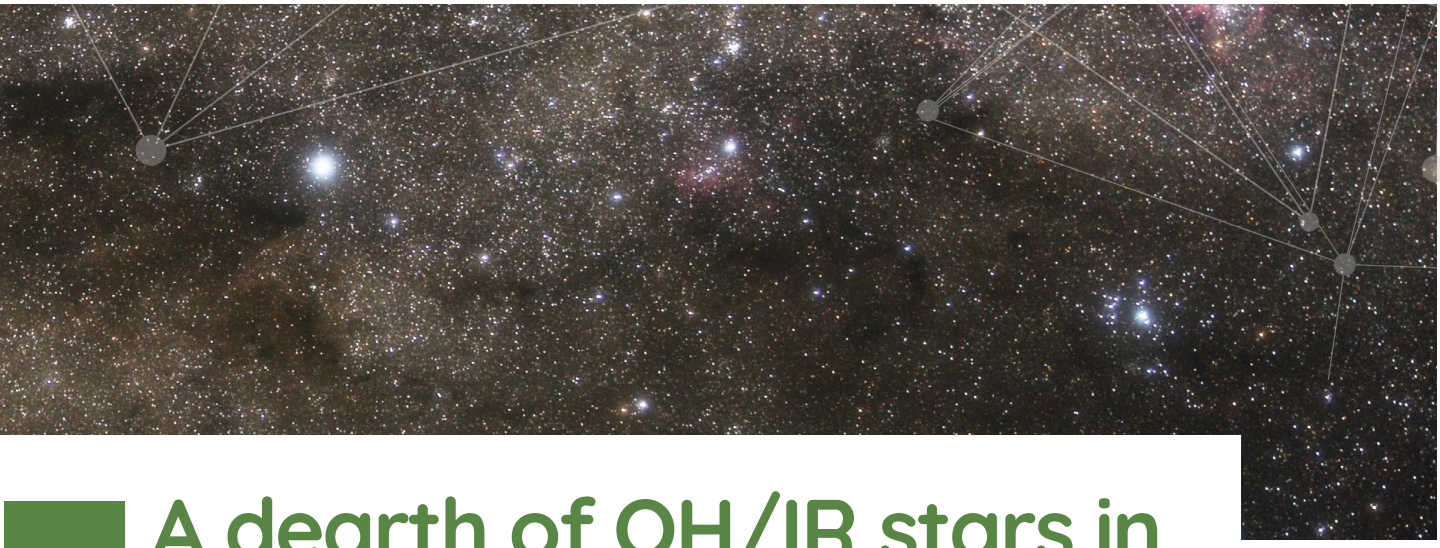
Caroline Huang from the John Hopkins University in the USA and her team (including Patricia Whitelock from SAAO) present year-long, near-infrared (NIR) Hubble Space Telescope (HST) observations of Mira variables in the water megamaser host galaxy NGC 4258. Oxygen-rich Mira variable stars follow a tight period-luminosity relation in the NIR with a scatter of ~0.14 mag and can therefore be used to measure extragalactic distances.

The water megamaser in NGC 4258 gives a geometric distance to the galaxy accurate to 2.6% that can serve to calibrate the Mira period-luminosity relation. Huang and her co-authors developed criteria for detecting and classifying O-rich Miras with optical and NIR data, as well as with NIR data alone. In total, they discovered 438 Mira candidates that can be classified with high confidence as O-rich. Their most stringent criteria produced a sample of 139 Mira candidates that they used to fit a period-luminosity relation. Using the OGLE-III sample of O-rich Miras in the Large Magellanic Cloud, they obtain a relative distance modulus ($\mu_{4258} - \mu_{LMC} = 10.95 \pm 0.06$ mag) that is statistically consistent with the relative distance determined using Cepheids. These results demonstrate the feasibility of finding and characterizing Miras in the NIR with the HST and the upcoming JWST and using those Miras to measure extragalactic distances and determine the Hubble constant.



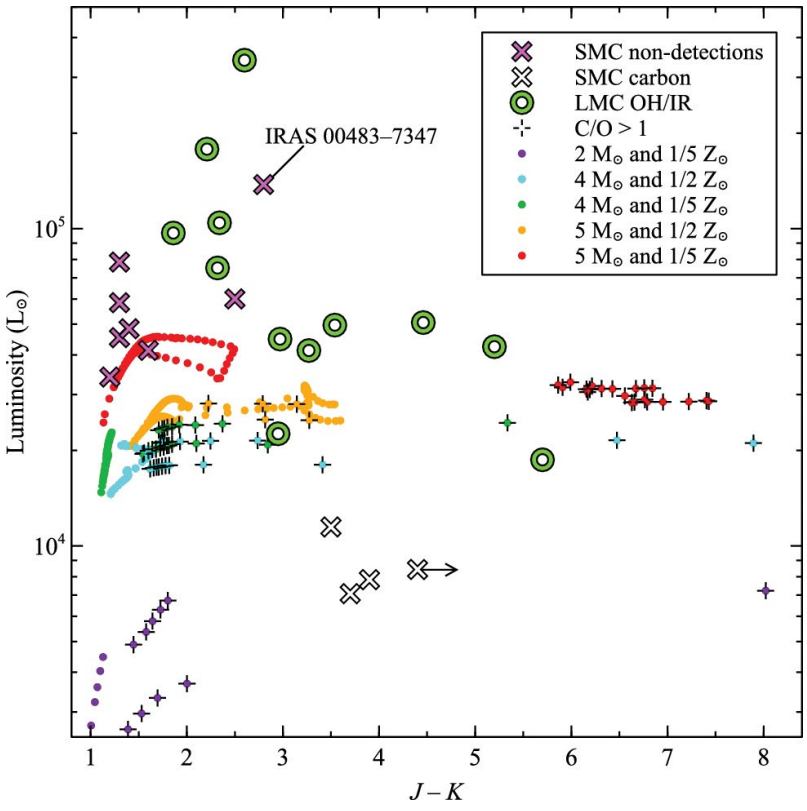
The Mira period-luminosity relation for the highest quality subsample of presumed oxygen-rich Miras in NGC 4258.

Huang, C.D., et al., 2018/04, ApJ 857, 67: A Near-infrared Period-Luminosity Relation for Miras in NGC 4258, an Anchor for a New Distance Ladder



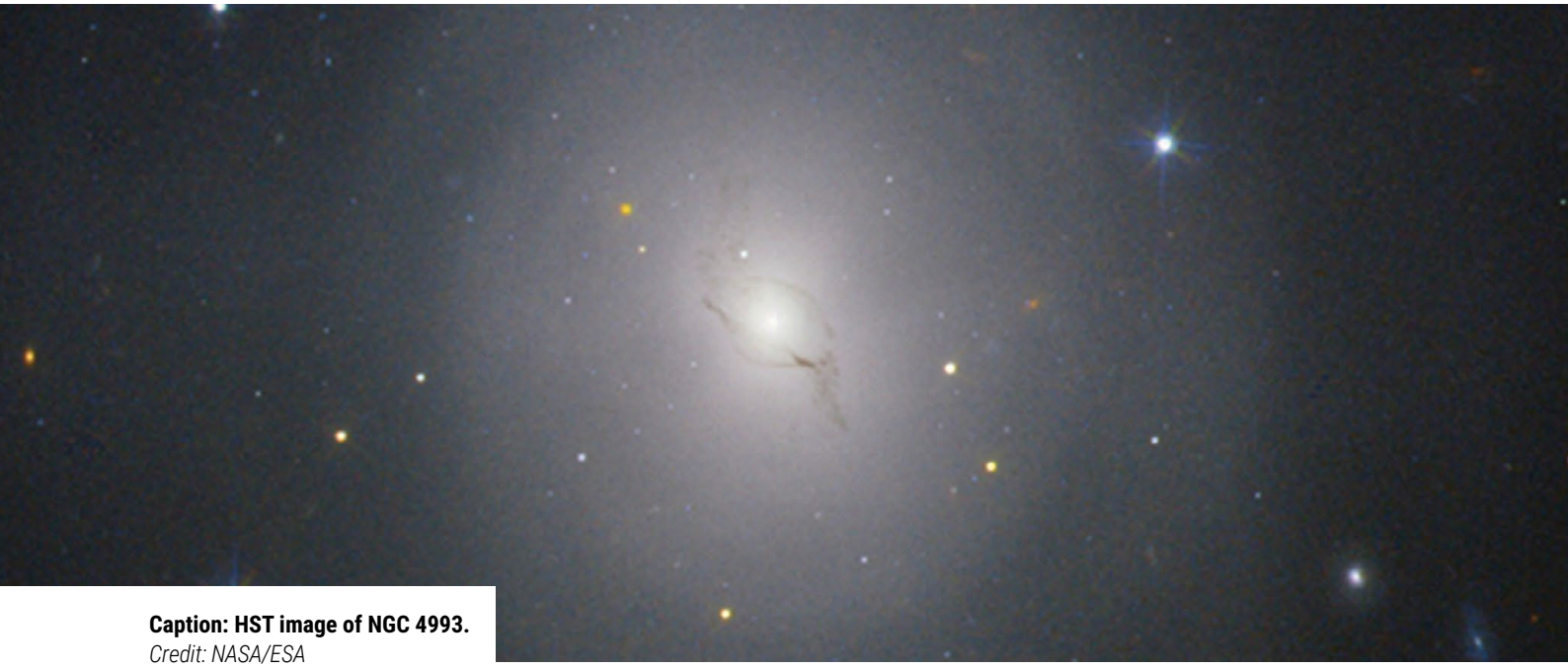
A dearth of OH/IR stars in the Small Magellanic Cloud

Steven Goldman from Keele University in the UK and his collaborators (also from SAAO) present the results of a search for circumstellar OH maser emission from AGB stars and red supergiants in the SMC, using the Australian radio telescopes Parkes and ATCA (Australia Telescope Compact Array). No clear OH maser emission was detected in any of the observations targeting luminous, long-period, large-amplitude variable stars that have been confirmed spectroscopically and photometrically to be mid-to-late M spectral type. The observations are 3–4 times deeper than any previous OH maser survey in the SMC. The authors then used a bootstrapping method to predict the likelihood of achieving a maser-pumping efficiency that would result in a 3σ level detection in their survey. By replacing each SMC source with a randomly selected maser efficiency from Galactic and LMC OH/IR-star samples, they calculated the collective probability of not achieving this detection level in the two brightest targets as less than 0.05%. The authors also performed a population comparison of the Magellanic Clouds and used Spitzer photometry to confirm that they have observed all high luminosity SMC sources that might be expected to exhibit maser emission. They suggest that, compared to the OH/IR stars in the Galaxy and LMC, the lower metallicity in the SMC may curtail the dusty wind phase at the end of the evolution of the most massive cool stars, concluding that the conditions in the circumstellar envelope change beyond a simple scaling of abundances and wind speed with metallicity.



The luminosity as a function of J – K colour for samples in the SMC and LMC; also shown are stellar isochrones corresponding to 2, 4 and 5 $M_\odot$ stars in their thermally pulsing AGB phase for both the LMC and SMC metallicities.

Goldman, S.R., et al. 2018/01, MNRAS 473, 385: A dearth of OH/IR stars in the Small Magellanic Cloud



Caption: HST image of NGC 4993.
Credit: NASA/ESA

SAAO observes the first optical counterpart of a Gravitational Wave source

Following the announcement of the discovery of a merging neutron star by the LIGO and VIRGO gravitational wave observatories on 17 August 2017, SALT and several SAAO telescopes partook in an unprecedented international collaboration to investigate the origin of these gravitational waves. The collaborative effort marks the birth of a new era in astrophysics: the first cosmic event observed using two messengers: gravitational waves and light.

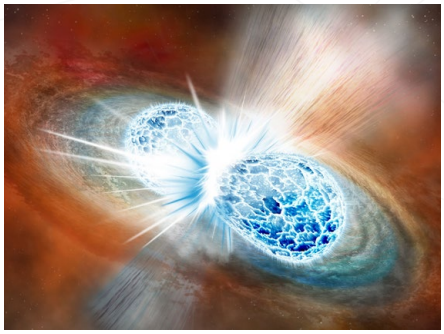
Background information:

- Gravitational waves were first detected only two years ago, with only three more detections since then, leading to the 2017 Nobel Prize in Physics being awarded to three US scientists. So far they had been all collisions from black holes and were not expected to emit any light. However, the new event, dubbed GrW170817, was the collision of two neutron stars, and for the first time ever light and gravitational waves from the same event could be observed.

- Neutron stars are the smallest, densest stars known. They are the remains of massive stars that exploded as supernovae. In this particular event, two such neutron stars spiralled inwards and then collided, emitting gravitational waves that were detectable for about 100 seconds. The collision also resulted in an explosion of light called a kilonova, initially in the form of gamma rays which were detected by space-based telescopes. The gamma rays were then followed by X-rays, ultraviolet, optical, infrared, and radio waves. This allowed astronomers to localise the event within hours and launch follow-up observations with numerous telescopes in South Africa and around the world.

SALT and other SAAO telescopes were among the 70 ground- and space-based observatories that observed the cataclysmic explosion of two colliding neutron stars, immediately after their gravitational shock waves were detected by the U.S.-based Laser Interferometer Gravitational-Wave Observatory (LIGO) and the European-based Virgo detector, providing some of the crucial first data.

Over the ten days following the discovery (see insert to the right), four of Sutherland's telescopes monitored the fading kilonova until it became too faint: (1) SALT's first spectrum (1.2 days after the explosion) shows a bright blue component that rapidly faded and was not present anymore in the second spectrum, obtained only 24 hours later. This initial blue component proved to be consistent with ultraviolet observations made at an earlier time with the Swift satellite. (2) Optical photometry was obtained with the MASTER-SAAO facility which is a southern hemisphere node of a global network of small robotic telescopes, operated from Russia, used to discover and observe "transient" events in the Universe like supernovae and gamma ray bursts. (3) The SAAO 1-m telescope also observed the kilonova, but the data quality was too poor to estimate meaningful magnitudes.(4) The near-infrared simultaneous imaging camera, SIRIUS, installed on the 1.4-m Japanese IRSF telescope was used between 6.2 and 9.2 days after the explosion.



An artist's impression of a kilonova, the result of two colliding and merging neutron stars, which was the source of the first gravitational wave event (GrW170817) for which an electromagnetic counterpart was detected at various wavelengths.
Credit: Robin Dienel; Carnegie Institution for Science.

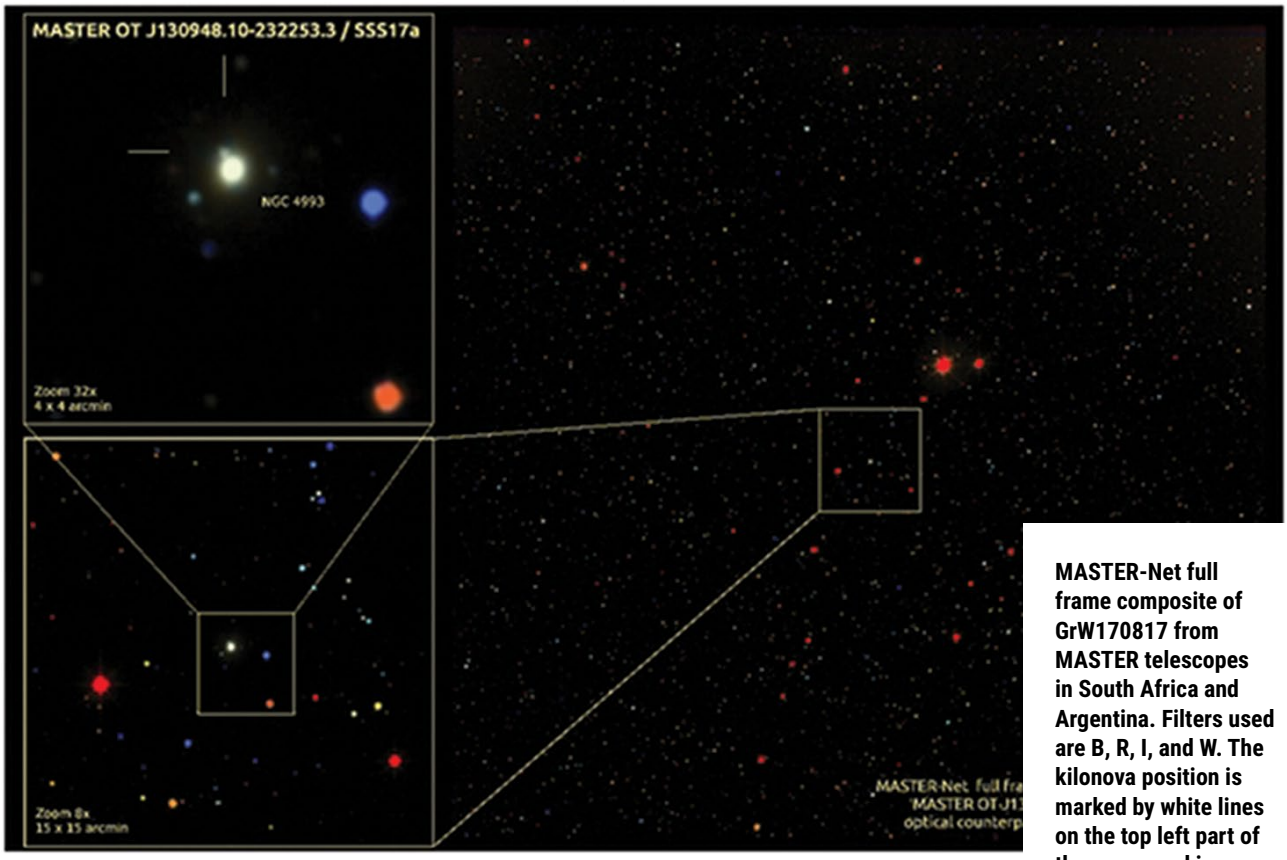
In particular, David Buckley from SAAO and his team combined the SAAO observations of the kilonova's brightness at three different wavelengths from the MASTER-SAAO facility to more accurately estimate the flux measurements made by SALT. These were then compared to recent models developed by a Japanese team, led by Masaomi Tanaka of the National Astronomical Observatory of Japan (NAOJ). The results, including the observations with the IRSF, were very interesting, showing a rapid reddening of the spectra over timescales of days, in broad agreement with the predictions of the latest kilonova models. The

- The significance of getting early observations stems from the afterglow of the collision changing very rapidly. Piecing together the new science from the event requires combining observations spanning the first hours, days and weeks after the merger. The first SALT spectrum has a very prestigious spot in the discovery publication with thousands of authors and hundreds of institutions.

- SAAO's and all the other observations, obtained over the days and weeks following the event, show that heavy elements, such as lead and gold, are created in these neutron star mergers and, driven by the powerful explosion, are subsequently distributed throughout the universe, becoming material from which new worlds are being formed.

The first day...

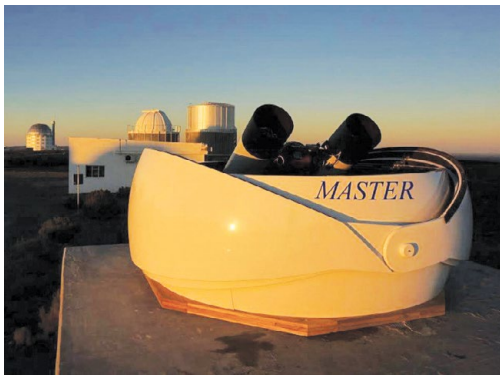
Friday, 18 August 2017, following the LIGO detection and the initial successful searches in Chile for the counterpart, was a busy day at SAAO's Sutherland site. After a flurry of messages and emails, Petri Väisänen finally got the coordinates: There was that new object, which had caused the whole of space-time to ripple, sitting at the outskirts of the galaxy NGC 4993 some 130 million light-years away. And everyone with a working telescope in the Southern Hemisphere was scrambling to get data on it. SALT decided to drop all other plans for that evening, and went for a spectral observation, for which SALT is famous. It turned out to be a difficult observation since the galaxy was only visible during twilight. Nevertheless, SALT succeeded and was the third observatory world-wide to provide a spectrum of the event, and it was the first spectrum that clearly showed anomalous behaviour, proving that this was no run-of-the-mill transient event.



MASTER-Net full frame composite of GrW170817 from MASTER telescopes in South Africa and Argentina. Filters used are B, R, I, and W. The kilonova position is marked by white lines on the top left part of the composed image. The right (large) image is the MASTER main telescope's usual FOV. *Credit: MASTER-Net/ NRF/SAAO*

results confirmed the conclusions of other investigators that the kilonova explosion, resulting from the rapid (less than a minute) merger of two neutron stars in orbit around each other, triggered the ejection of a fast outflow of material (at 5% – 10% the speed of light), which was observed at a high angle to the orbital plane of the neutron stars.

The results of this unprecedented event have demonstrated the importance of collaborative multi-messenger observations and mark a new era in astronomy. The success of SAAO's observations are not the least due to the team work that ensured that the observations were promptly undertaken and the data reduced quickly. Owing to the quick response of SALT and other SAAO telescopes, crucial information on the nature of the gravitational wave source



The MASTER-SAAO telescope at Sutherland.

was thus obtained. These have resulted in the publication of eight refereed papers containing these observations. The detection of an electromagnetic counterpart to a gravitational wave source, coming only two years after the first gravitational wave detection, bodes well for the study of future gravitational wave neutron star merger events.

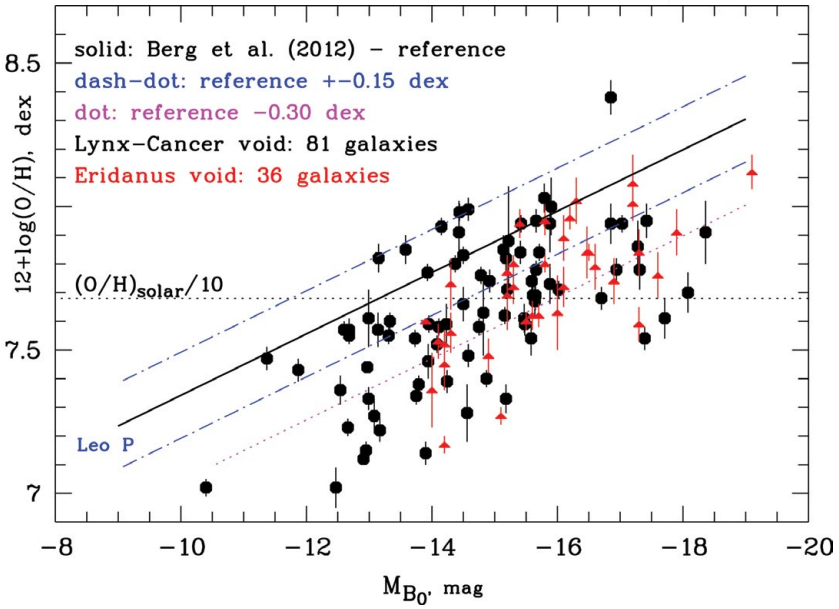
Buckley, D. A. H., et al., 2018/02, MNRAS 474, L71: A comparison between SALT/SAAO observations and kilonova models for AT 2017gfo: the first electromagnetic counterpart of a gravitational wave transient - GW170817

SALT reveals under-abundant galaxies in the Eridanus void

Galaxies live in different environments: they appear in rich clusters, being so close to each other that gas and sometimes stars are ripped out of them, they live in tenuous filaments and wall-like structures that connect the rich clusters, and they even can be found in the so-called voids, areas virtually empty of galaxies – but not quite. The modern cosmological Λ–CDM models of large-scale structure and galaxy formation predict that galaxy properties and their evolution can significantly depend on the global environment. The role of the most rarefied environment, typical of voids, however, is not well studied either theoretically or observationally.

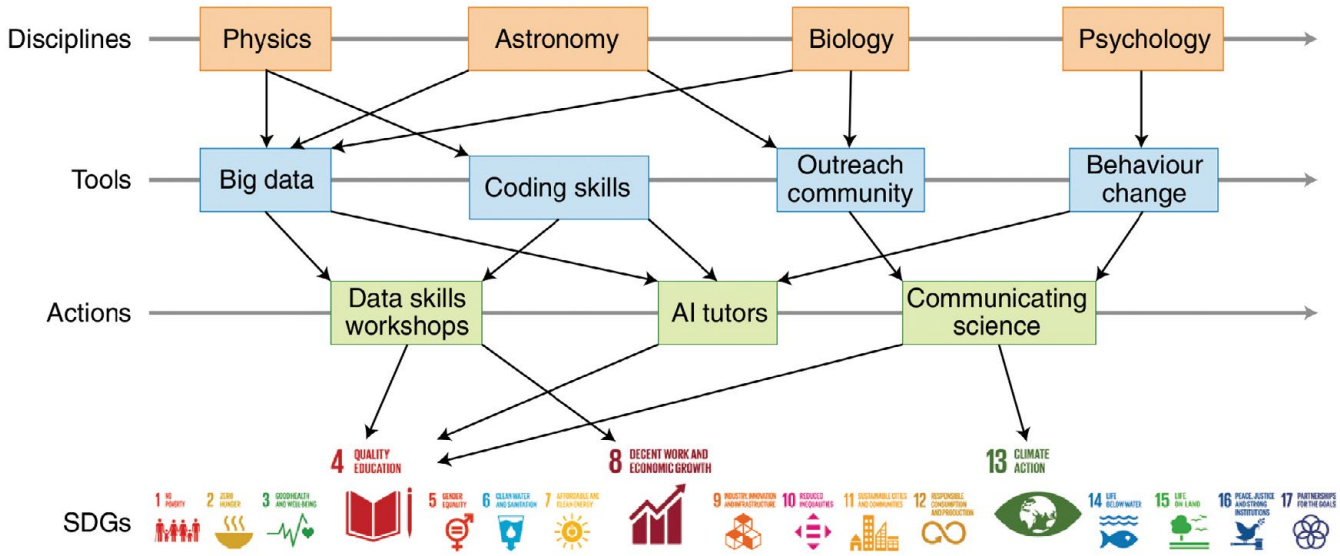
In particular, most of the mass studies of galaxies in voids, based on large samples from the SDSS spectral database, are limited to rather distant, giant voids (at D ~ 100 – 200 Mpc) and hence probe only the upper part of the void-galaxy luminosity function. Besides, analyses presented in the literature so far are based on SDSS data precluding the direct study of the evolutionary status of void galaxies. While some differences were found in the global properties of void galaxies with respect to that of the wall population, they are rather modest. Thus one could conclude that for the upper mass/luminosity range the effect of the void environment is rather subtle.

Alexei Kniazev from SAAO and his Russian colleagues decided to study this effect in more detail with SALT and report on properties of galaxies in the nearby, very low-density region known as the Eridanus void (D ≲ 50 Mpc). The main goal of their project was to study systematically the evolutionary parameters of the void sample (that is, metallicity and gas content) and to compare the void galaxies with their counterparts residing in denser environments. They selected a sample of 66 galaxies belonging to this void based on the criterion that a void galaxy is to be separated from any luminous galaxy delineating the void by at least 2 Mpc. Data for 23 of these void galaxies were obtained with the Robert Stobie Spectrograph on SALT, while the data for the rest were compiled from other sources. By comparing all their void-galaxy data with a control sample of galaxies with similar morphological types in the Local Volume, the authors find that there is clear evidence for a substantially lower average metallicity for the Eridanus void galaxies.



The relation between log (O/H) and the absolute blue magnitude MB for 36 Eridanus void galaxies (red triangles) and 81 Lynx–Cancer void galaxies (black circles). The solid line shows the linear regression for the control sample from the Local Volume. The dotted line (displaced at –0.30 dex from the reference line) separates the region where the most deviating metal-poor dwarfs are situated.

Kniazev, A.Y., et al., 2018/09, MNRAS 479, 3842: Study of galaxies in the Eridanus void. Sample and oxygen abundances



The potential of astronomy for socio-economic development in Africa

An illustration of science for development, where astronomy is only a part of the broader contribution of science towards the SDGs. Some examples of science disciplines are listed at the top, tools related to their disciplines in the second horizontal layer, possible actions in the third and the SDGs at the bottom. The downward cascading arrows indicate paths along which potential projects, using tools from different disciplines, may result in actions that contribute to the SDGs. *Credit: SDG icons courtesy of UN/SDG*

The prestigious journal Nature Astronomy dedicated their commentary section in the July 2018 edition to astronomy in Africa. Vanessa McBride from SAAO and the OAD, together with her colleagues, contributed to this series. Their article highlights the challenge of ensuring that educational, technology transfer and societal engagement initiatives that drive socioeconomic development take place alongside the growth of astronomy on the African continent.

MvBride lists a number of projects undertaken in Africa and funded by the International Astronomical Union's Office of Astronomy for Development (IAU-OAD). These projects range from initiatives focusing on education and literacy to health and skills transfer. In addition, the article references the many other astronomy-related development initiatives that form part of the ecosystem of astronomy on the continent.

The authors particularly note that many of the challenges facing Africa and the world have solutions that are driven by human values, and no amount of science or technology can solve these issues without accounting for the needs, values and behaviour of the people in these milieus. For astronomy, and other sciences, making connections across disciplinary fields is essential to contribute socioeconomic development issues in Africa.

McBride, V., et al., 2018/07, Nature Astronomy 2, 11: The potential of astronomy for socioeconomic development in Africa

SAAO OPERATIONS

Technical operations report

The technical department comprises the instrument section, the mechanical and electronic workshops and a dedicated CCD lab. Apart from the necessary maintenance, new instruments, or parts thereof, are developed here for our telescopes. Our engineers also research more efficient ways to run these instruments and the telescopes.

The SAAO instrumentation group has designed and built a wide-field imaging camera named Sibonise (meaning "show us" in isiXhosa). The hardware, including cryostat and auxiliary control systems, has been tested in an environmental chamber in the optics lab in Cape Town, which simulates the operating temperatures that will be endured in Sutherland.

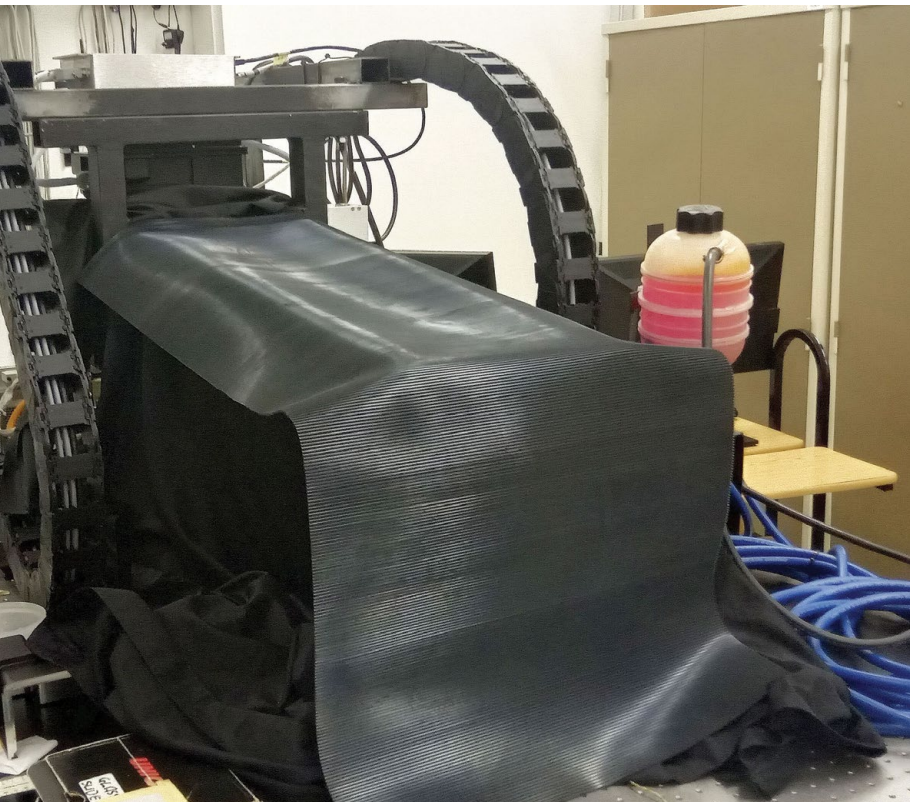
The instrument incorporates some new technologies, including a large-format shutter designed and built in-house, and a detector controller developed in collaboration with SALT partner IUCAA (Inter-University Centre for Astronomy and Astrophysics, Pune, India).

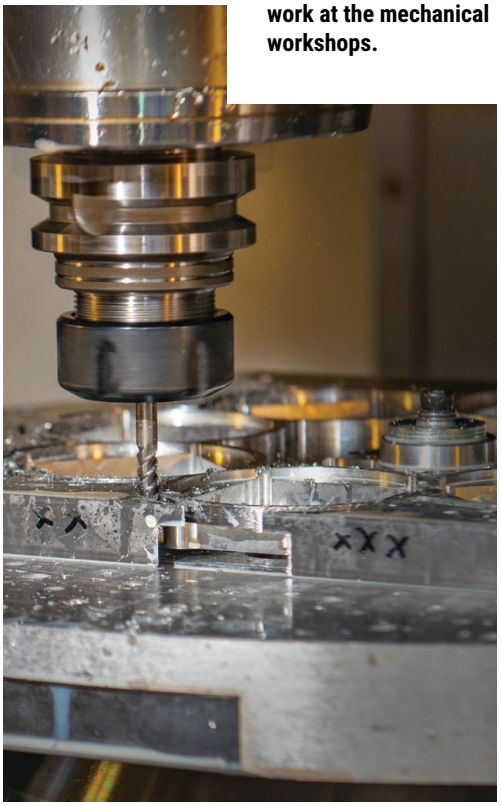
Sibonise is undergoing final software testing and development work in the laboratory before deployment to the Lesedi telescope in Sutherland.

Sibonise's control software has been created using the distributed software architecture developed in accordance with our intention to make the telescopes and instruments remotely – and eventually robotically – operable. Our software team has produced such systems for Sibonise and Lesedi this year, both featuring a web interface for direct control by astronomers, and a scripting interface for scheduled interactions.

Left: Sibonise during the ATP (Acceptance Test Procedure) phase. Under the black cover is a projector that provides an image or flat field for testing the CCD and subsystems. The tank on the right contains glycol for water cooling the sterling cooler. Also visible are the two cable wraps which will be handling then cables when mounted on the derotator of the Nasmyth focus on Lesedi.

Below: High-precision work at the mechanical workshops.





After consultation with the South African astronomical community, it was decided to acquire two spectrographs for Lesedi. The first is a low-resolution, high-throughput spectrograph, largely for follow-up observations of transient objects. Liverpool John Moores University (LJMU) in the UK bid successfully to supply the instrument, and are now working with the team at SAAO on the specifics of the design. The estimated completion is mid 2020. Secondly, we are developing an innovative, fibre-fed, high-resolution echelle spectrograph, to support exoplanet observations. The project is in the planning and procurement stage.

As Lesedi is designed to be a remotely-operable telescope, we are designing a multi-instrument mount so that both spectrographs and a fast imaging camera can all be mounted on the same port on the telescope, to allow the required instrument to be selected at the touch of a button. The second port will be dedicated to Sibonise, which will be just as simple to select.

The 1.9-m telescope continues to operate a spectrograph (SpUpNIC – Spectrograph Upgrade Newly-Improved Cassegrain), polarimeter (HIPPO), and an imaging camera (SHOC – Sutherland High-speed Optical Camera), all developed at SAAO.
The 1.0-m telescope offers three different imaging cameras and is the target telescope for a new polarimeter being developed with IUCAA.

In collaboration with the University of Hawaii, SAAO will be installing an Asteroid Terrestrial-impact Last Alert System (ATLAS) at Sutherland. This is a telescope that scans the sky several times each night in order to provide an early warning of asteroid impacts.

Construction of the dome and installation of the first solar-power facility on the Sutherland plateau is expected to commence in late 2019, with the aim of providing power for ATLAS and taking the first step toward renewable energy at SAAO.
The mechanical workshop has been highly productive, as always, producing components for the instruments we are building and maintaining, as well as fabrication work for other organisations in need of our specific expertise. Ongoing manufacturing for the NRF facility iThemba Labs includes target holders, different versions of lead pots to hold radioactive isotopes, and various once-off, precision-machined components. A joint SAAO/TLABS workshop identified additional production that the mechanical workshop is undertaking for them. Many new enquiries for machining and inspection have also been received from SARAO. Two new operators, two apprentices on the SARAO-SAAO joint training scheme, and a new dual spindle machine (arriving in October 2019) will help to keep up with the workload.

Efforts are also devoted to the SALT RSS (Robert Stobie Spectrograph) detector upgrade. The various options for the RSS detector upgrade are being investigated with a view to improving the robustness of the RSS instrument and to further the capabilities of the instrument to better meet increasing scientific demand. Upgrade options include the elimination of mosaiced CCD chips to new large scale format monolithic CCDs with better quantum efficiencies, fringing and noise properties. These studies will inform the maturing of the Requirements and Specifications for the new detector package for review by the SALT stakeholders.

As Lesedi is a remotely-operable telescope, we are designing a multi-instrument mount so that both spectrographs and a fast imaging camera can all be mounted on the same port on the telescope, to allow the required instrument to be selected at the touch of a button.

Astronomy operations

SAAO telescopes report

SAAO's observing station near Sutherland is home to many optical and infrared telescopes, ranging from the very large (SALT) to small with a huge field of view (KELT), to those having very large CCDs (KMTNet with 18k x 18k). They allow a range of observing modes from spectroscopy (both low and high resolution), photometry (including high-speed, optical and IR imaging) and polarimetry. Observing time on SAAO's 1.9-m and 1.0-m telescopes is available on a competitive basis to astronomers world-wide, and all applications go through a TAC process. Lesedi will join the two SAAO telescopes once it is fully commissioned. Observing time on SAAO's co-owned IRSF is available to South African and Japanese astronomers and their collaborators.

Observing time on the 1.9-m and 1.0-m telescopes is given in blocks of weeks; this is a logistical requirement related to transporting observers from Cape Town to Sutherland as well as instrument changes requiring some technical efforts that can only be done during the day. Subscription levels in the table are given as the average fraction of weeks applied for relative to the number of available weeks per trimester. The subscription levels include all the applications received before the deadline as well as subsequent applications for unallocated observing time after the deadline and applications for occultation observing time. The latter usually require only a small fraction of the night (in hours) but they are considered to be contributing one night to the subscription levels since they often require an instrument change.

Trimester	1.9-m (%)	1.0-m (%)
Trimester I (Jan - Apr)	100	100
Trimester II (May – Aug)	100	94
Trimester III (Sep - Dec)	86	100
Total	95	98

Table 1: Observing time subscription levels on the 1.9-m and 1.0-m telescopes for 2018.

Remote observing

All the three SAAO telescopes (1.9-m, 1.0-m and Lesedi) are remotely operable with some of the instruments: The Sutherland High-Speed Optical Camera (SHOC; available for all three telescopes) and the spectrograph SpUpNIC (Spectrograph Upgrade – Newly Improved Cassegrain on the 1.9-m). Lesedi has been remotely operable right from the beginning and has a suite of instruments that is easily selectable without the need for an instrument change. The 1.0-m and 1.9-m telescopes have been equipped for remote observing recently and instrument changes still require considerable manual effort and can only be done during the daytime.

While SHOC is frequently being used remotely without any issues, remote operation observations with SpUpNIC work but still require some of the operations to be done manually at the telescope, like taking dome flats (which requires the telescope to be pointed into the software limits) and changing gratings and filters. With the remote observing modes on the SAAO telescopes becoming available, it will no longer be necessary to offer observing time in blocks of weeks.

The temporary remote control room in Cape Town in the East Wing of the main building.

Hosted facilities

SAAO not only provides research platforms for South African and international astronomers, it also hosts many national and international research facilities at Sutherland. These include both telescopes and geophysical facilities. Most of the hosted facilities pay what is called an annual site or facility fee. Those that require a larger bandwidth, that is, above the 1.5 Mbps provided as part of the facility fee, also pay for internet bandwidth. Facilities that are co-owned by SAAO or where SAAO is part of the collaboration, do not pay facility fees (e.g., MeerLICHT and IRSF).

Some facilities give the South African astronomy community access to observing time: KMTNet allocates four blocks of 10 nights between October and February to SAAO usage, constituting about 10% of the total observing time. LCO, on the other hand, allocates 10% equivalent time for each of the telescopes hosted at SAAO over their entire network, that is, with the three 1-m telescopes and one 0.4-m telescope at Sutherland, SAAO's 4 x 10% observing time can be taken at any telescope of the world-wide network (two 2-m telescopes, nine 1-m telescopes, and seven 0.4-m telescopes placed at six astronomical observatories).

Other telescope facilities usually have a clause in their agreement indicating that they will give SAAO users access to their database, usually for science that is not related to the main scientific objective of the facility. For example, some South African astronomers make use of the data from the SuperWASP* database for their scientific publications on non-exoplanet related studies.

Future telescope projects

Two telescopes will be constructed at Sutherland in the near future. The ATLAS (Asteroid Terrestrial-impact Last Alert System) is a NASA-funded automated system of telescopes designed for searching for incoming near-Earth asteroids (that is, asteroids on a trajectory towards an impact or close approach with Earth). The ATLAS project is a collaboration between the University of Hawaii ATLAS Project and SAAO. The telescope will be similar to the two 0.5-m ATLAS telescopes currently in operation in Maunaloa and Haleakalā in Hawaii. The second planned telescope is PRIME (or PRime focus Infrared Microlensing Experiment), a 1.8-m IR telescope dedicated to a project called "Infrared Gravitational Microlensing Survey". PRIME is a collaborative project between SAAO and the University of Osaka in Japan.

Some facilities give the South African astronomy community access to observing time: KMTNet allocates four blocks of 10 nights between October and February to SAAO usage, constituting about 10% of the total observing time.

*The telescope is now decommissioned.

Research groups

SAAO's astronomers have formed three research groups to stimulate research between people who share common scientific interests. These groups can be cross-disciplinary and involve members of multiple institutions.

Stellar astrophysics group

South Africa has had a long and rich history of stellar astronomy, for example, the first ever measurement of the distance to a star (Alpha Centauri) was made here in 1833. Today we continue this tradition, working on multi-wavelength observations and numerical simulations of a wide range of stellar systems including:

Time Domain Astronomy – involving a large collaboration of researchers from SA and abroad. A multi-semester programme on SALT (PI: D. Buckley) is used to follow-up astrophysical transients from local (e.g. the MASTER telescope) and international facilities (e.g. SPIRITS). This area of research is growing rapidly, more recently through collaborations with the ThunderKAT team in the radio (transients with MeerKAT) and MeerLICHT follow-up for the optical, and with LSST in the near future.

Interacting binaries – teams working on cataclysmic variables, symbiotic and X-ray binaries, identifying binaries in planetary nebulae.

Variable stars – e.g., pulsating red giants, and the period-luminosity relation for distance scales and tracing galactic structure.

Computational stellar astrophysics – 3D models of mass transfer in binaries, planet-star interactions, transients and stellar.

Stellar explosions – e.g., stellar mergers, novae and supernovae.

Weekly group meetings on Friday at 11am bring all these teams together. Non-SAAO researchers are also welcome.

Planetary astronomy group

We have an active, professional planetary science research at the SAAO. These days, the work is primarily focused on small bodies in the Solar system. In particular, we study trans-Neptunian object dynamics and colours, observe and analyse stellar occultations by trans-Neptunian objects (especially Pluto), and measure asteroid colours. There is also interest in planetary space missions.

Occultation observations (the light from a star being blocked as it passes behind a foreground object) require high-cadence, low-deadtime, accurately-timed, high-quality images. Instruments capable of these requirements are not readily available on telescopes around the world; therefore, SAAO researcher Amanda Sickafoose has been involved in building such instruments. For example, the SHOC instrument, which is now installed at the telescope Lesedi, has been frequently used to observe stellar occultations by Pluto, Chiron, 55636, and other TNOs.

Galaxies group

A number of people at SAAO are working on extragalactic astronomy and galaxy evolution and have formed an informal galaxies group. We meet roughly every fortnight to discuss the latest research, share ideas and encourage students and postdoctoral fellows working in the field to present their work and to get feedback. The wide range of research interests explored include star formation in galaxies, active galactic nuclei (AGN), feedback processes from supernovae and AGN, ultra-diffuse galaxies, evolution of brightest cluster galaxies (BCGs) and mergers of galaxies.

These topics are mostly explored from an observational angle, using optical, near-infrared and radio data from telescopes around the world, but there are also researchers simulating galaxy formation using high-performance computer clusters at SAAO and elsewhere. SALT is being used by researchers at SAAO to study very faint dwarf galaxies in nearby voids, star-forming rings around lenticular galaxies, kinematics and outflows from galaxies, galaxy mergers in distant clusters and galaxies that will be observed by the MeerKAT large programmes LADUMA and MIGHTEE.

One of the recent highlights for the galaxies group at SAAO is the start of a new large science programme on SALT to measure the distances to and properties of BCGs. This collaboration between SALT partners in South Africa (led by Matt Hilton, UKZN), India and the USA, will use SALT to observe BCGs identified by the Advanced Atacama Cosmology Telescope (AdvACT) telescope out to very large distances. Complementary data from SALT and the MeerKAT radio array will allow the study of star formation histories and gas content of these galaxies, which will improve our understanding of how massive galaxies grow and change over time and how the most massive structures in the universe build up.

Student support

With a view to (1) providing higher levels of support to both student and supervisor and (2) trying to get more students to completion on the prescribed timescale, the following measures have been put in place for those students who are primarily based at the SAAO:

- Each PhD student has a postgraduate advisory committee (PAC) which meets once a year, with and without the student and supervisor(s), to discuss progress. In the first year, they review the research proposal, and in subsequent years they attempt to identify any serious problems and make suggestions for additional support should it seem necessary. PACs can also be organised for MSc students if they and their supervisor consider it helpful.

- A student coordinator (astronomer) and a student administrator have been appointed to streamline the process of supporting students within SAAO.

- Top-up funding to bursaries/grants has been provided, so that all students sitting at SAAO receive the same funding, at a respectable level. In return for this, the students work 40 hours per year (i.e. approximately one hour per week) for SAAO.

- The work the students are required to do is intended to help develop essential skills. It includes service observing, remote observing and helping with open nights and/or with school visits.

- Two large offices, suitably furnished, have been set aside for use by the students.

- Students may elect to meet once a fortnight with a professional tutor to study English in a "writing circle". The emphasis is on writing scientific papers, but the students also use the opportunity to develop their spoken language and presentation skills.

- The students are encouraged to attend colloquia and journal clubs to broaden their general scientific knowledge.

- A system of mentors comprising young staff astronomers or postdocs, has been established. They meet their assigned student a few times a year, or when required, and offer advice and support on academic and other matters.

- An SAAO Student Representative (SSR) is elected from among the students and meets monthly with the Student Coordinator and Student Administrator to improve communications, to deal with matters of mutual interest and to ensure that any problems are dealt with timeously.

Students may elect to meet once a fortnight with a professional tutor to study English in a "writing circle". The emphasis is on writing scientific papers, but the students also use the opportunity to develop their spoken language and presentation skills.

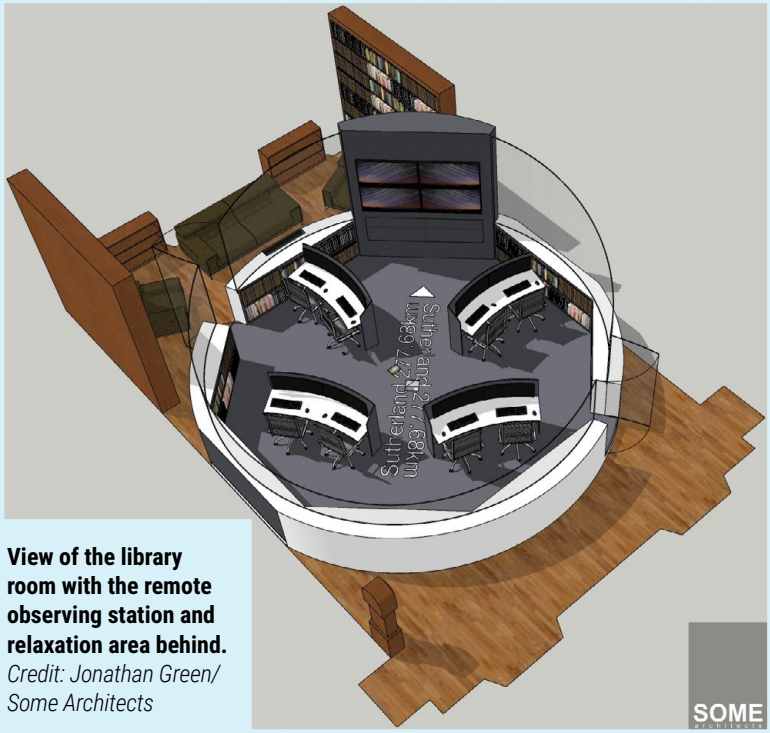
Design image of the remote observing station, showing the screen of the night sky above.
Credit: Jonathan Green/ Some Architects

The African Intelligent Observatory (AIO) programme

SAAO's strategic plan for the next decade will move the observatory into the era of the Fourth Industrial Revolution (the combination of software with AI and advanced connectivity): The SAAO Intelligent Observatory (also known as the African Intelligent Observatory, AIO) will substantially increase the efficiency of observing programmes through automated observations of predominantly transient targets, but also of other types. The vision of the Sutherland observatory is to eventually have all SAAO telescopes tied into the AIO network. Multiple hosted facilities are also anticipated to contribute, providing triggers and/or follow-up observations.

The primary science driver for the AIO is time-domain and transient science. Critical to the success of the science in the rapid and intelligent use of the Sutherland telescopes to react to triggers/alerts from other ground- and space-based observatories. Triggers from LIGO/ Virgo and MeerKAT will likely be the highest priority initially for the AIO, with SKA, CTA and LSST providing opportunities in later years.

To fully capitalise on time domain and transient science, intelligent algorithms will be developed to filter and prioritise the deluge of candidates and select only the most interesting and relevant targets for follow-up. Determination of the magnitude of a target is done with optical imaging and identification of unknown-origin triggers are best done with a relatively low resolution spectrograph for example.



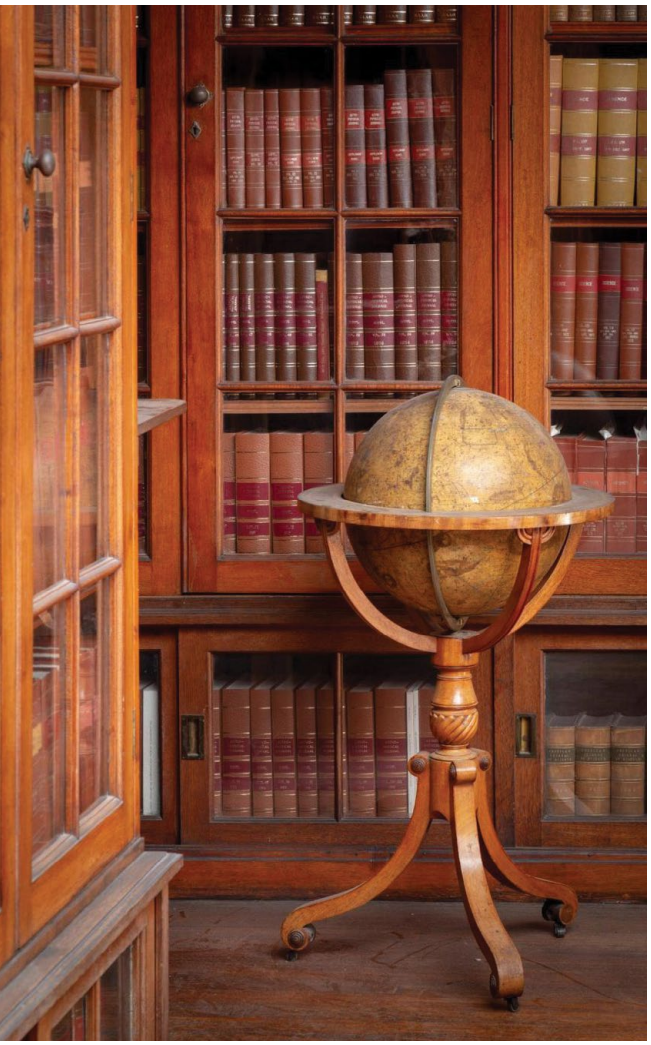
View of the library room with the remote observing station and relaxation area behind.
Credit: Jonathan Green/ Some Architects

Remote observing station

To support the AIO, a state-of-the-art remote observing station is planned at SAAO's headquarters in Cape Town. It will be placed in one of the current library rooms, divided into a relaxation area and a circular platform for the observers with desks, computers and a bank of monitors. The futuristic vision combines a high-speed, high-data-rate link with a virtual representation of the Sutherland site where the live night sky is projected on a screen above, and speakers on each desk project the live noises from the relevant telescope domes to ensure immediate feedback when any equipment is moved. The station will be encased in glass walls so that dignitaries and the general public can experience real-live action of astronomers at work.

Under the AIO, the various optical/IR facilities at Sutherland will be tied together into a network that can efficiently carry out standard observations and respond to triggers autonomously. The system will work collectively and intelligently, satisfying the needs both of standard observing and fast, efficient responses to triggers. The full ambition of the programme includes employing all telescopes and instruments, including SALT. Some of these instruments are still under development and need to be completed. Some telescopes require hardware modifications in order to be remotely, and then robotically, operable as well as to allow instrument selection. Software must be developed to run the processes and control all the hardware and automatically reduce and analyse observations in real time.

Supporting departments



Library and Information services

In 2018, Phase 1 of the SAAO Library Heritage Collections Digitization Project was completed with the scanning of over 96,000 pages from 196 Meteorological Report books (dated 1842 – 1960), 350 Astronomers' notebooks (dated 1844 – 1884) and the capturing of metadata for 8 000 photographs. In an attempt to deal with the lack of space, 168 metres of mobile shelving units were installed to provide shelving space for monographs. Staff and students were provided with access to a total of 844 e-books and 142 journals (both online and in print). There were over 10 000 full-text articles requested and downloaded from online journals.

The library provided data from the library's publications database for the required quarterly Key Performance Indicator reports on publication output by SAAO authors as well as by visiting authors affiliated to the SAAO. A total of 118 staff papers were submitted for the Research Innovation Reward Programme (RIRP) resulting in over R3 million being awarded.

Upgraded SALT control room.

Information and Technology services

The year 2018 has seen a few upgrades in IT services. The old network equipment has been replaced and the network coverage was improved around both sites. This included also the roll-out of Eduroam, which is an international roaming service for users in research, higher education and further education. This means that visitors from universities and other higher education centres around the world can easily access the internet without requiring extra access permission. For

faster network speed between the two sites, the Sutherland wireless backup link with Breedenet was finally upgraded from 10 Mbps to 100 Mbps. This will particularly ease the download of data from site and is an important step towards the remote observing. We also upgraded our Proxmox Virtual Environment in our Cape Town and Sutherland Data Centers. Proxmox Virtual Environment is an open-source server virtualization environment. It is a Debian-based Linux distribution with a modified Ubuntu LTS kernel and allows deployment and management of virtual machines and containers. In December, Chantal Fourie and Iriwaan Simon went to the Docker conference in Barcelona; since then IT has started to deploy docker for quite a few services, expecting to be able to use this technology for most of the future deployments.

At the Sutherland site, we assisted the Electronics department with the upgrade of the control rooms for the 1-m and 1.9-m telescopes, which was completed by the beginning of this year. We also liaised with the SALT astronomers to modernise the SALT control room by providing a solution using the software application Synergy which is used for sharing a keyboard and mouse between multiple computers. Synergy is used in situations where several PCs are combined, with a monitor connected to each, but controlled by a single user, which means, the user has only one keyboard and one mouse on the desk. In case of the SALT control room that meant to replace 4 x 24" monitors with 2 x 38" curved monitors and 3 keyboards and mice with the single keyboard and mouse.

At the Cape Town site, the work on the remote control room has begun: We drew up a specification, ordered and installed all IT hardware and software requirements for the proof of concept remote control room for the steerable telescopes and SALT. The remote control room was also equipped with the curved screens, which are ergonomically more pleasing and make it easier for astronomers to see all the content from various computers (rather than having 4 separate monitors which are more difficult to scan with a quick glance). In addition, we drew up the specification and cost estimate of IT infrastructure for the new remote observing station for the intelligent observatory, which will be situated in the library area.

Operations highlights

Inauguration of the MeerLICHT telescope

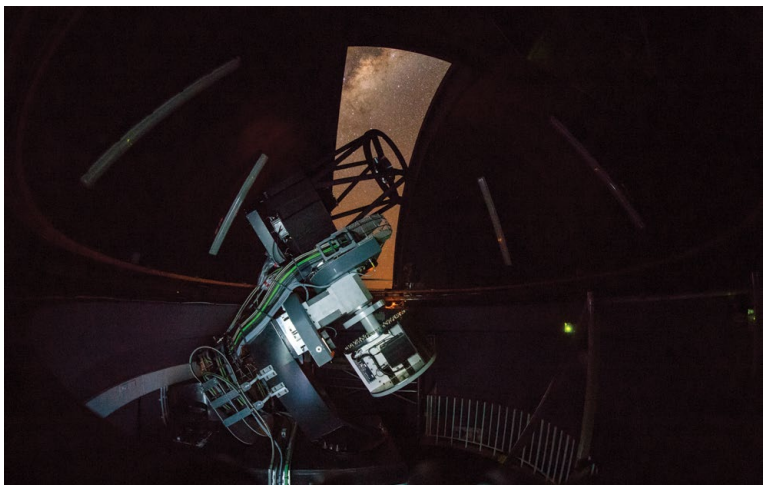
On Friday, 25 May 2018 – Africa Day – a new telescope was inaugurated at SAAO's Sutherland site. It will become the "Eye of the MeerKAT radio array", the country's precursor to the Square Kilometre astronomers will be studying stars and galaxies in two parts of the spectrum at the same time.

The project is a Dutch / South African / British collaboration involving researchers from six different institutes from the respective partner countries. MeerLICHT is a good example of a project aligned to the objective of the Multi-Wavelength Astronomy (MWA) strategy, which was approved by the Department of Science and Technology (DST) in 2015. The aim of the MWA strategy is to forge closer ties between the radio, optical and gamma-ray astronomy communities and facilities and to work together to achieve common scientific objectives and to develop human capital. Among the chief scientific goals of MeerLICHT is the study of stellar explosions, which need to be investigated intensely before they fade away again.

Its launched was set on Africa Day to recognise and celebrate both our incredible African skies and the important partnerships between Europe and Africa that have led to this innovation. Speaking at the inauguration of the telescope, DST Director-General Dr Phil Mjwara said that South Africa had chosen astronomy as the field of science to show its abilities in research on a global scale, to bolster technological development in the fields of telecommunication, Big Data and large-scale computing, and as the field best able to bring science to the people.

MeerLICHT was purpose-built to combine excellent resolution with a wide field of view. Its field of view is more than 13 times the full Moon and it is able to see objects one million times fainter than is possible with the naked eye. The telescope achieves this amazing combination by coupling a 65-cm diameter main mirror with a single 100 megapixel detector, which is 10 cm x 10 cm in size. It is the largest single detector used in optical astronomy anywhere in the world. The telescope was designed and built in the Netherlands, and then shipped to South Africa.

The unprecedented link with the MeerKAT radio array excites astronomers across the world. "Besides extreme astrophysics, typically associated with black holes and neutron stars, we will also study normal stars, in particular



MeerLICHT is a wide-field, fully robotic 0.65-m optical telescope, located at the Sutherland station of SAAO, which is one of the darkest astronomical sites in the world. By exclusively linking MeerLICHT to MeerKAT, the telescope will, for the first time ever, provide optical multi-band observations of every night-time observation conducted by a radio telescope.

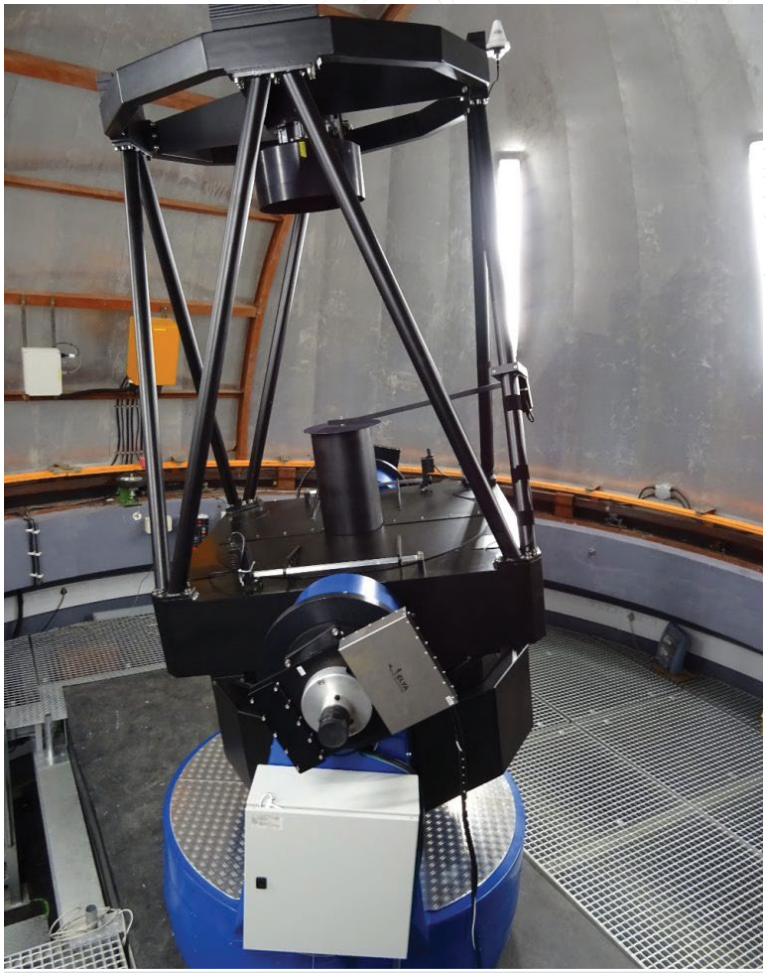
those that produce strong flares" says Prof. Rudy Wijnands of the University of Amsterdam. "The simultaneous optical-radio monitoring of these stars will allow us to investigate the impact of such flares on the habitability of the planets around them." MeerLICHT will directly link the whole optical observatory, and especially the 10-m SALT telescope, to the MeerKAT array. It fits perfectly in with SAAO's strategy to turn the Sutherland Observatory into an efficient transient machine to study the dynamic Universe.

The MeerLICHT consortium is a partnership between Radboud University Nijmegen, the University of Cape Town, the South African Astronomical Observatory, the University of Oxford, the University of Manchester and the University of Amsterdam, in association with the South African Radio Astronomy Observatory (SARAO), the European Research Council and the Netherlands Research School for Astronomy (NOVA). SAAO and SARAO are National Facilities of the National Research Foundation (NRF). The detector's cryostat was built at the KU Leuven, Belgium.

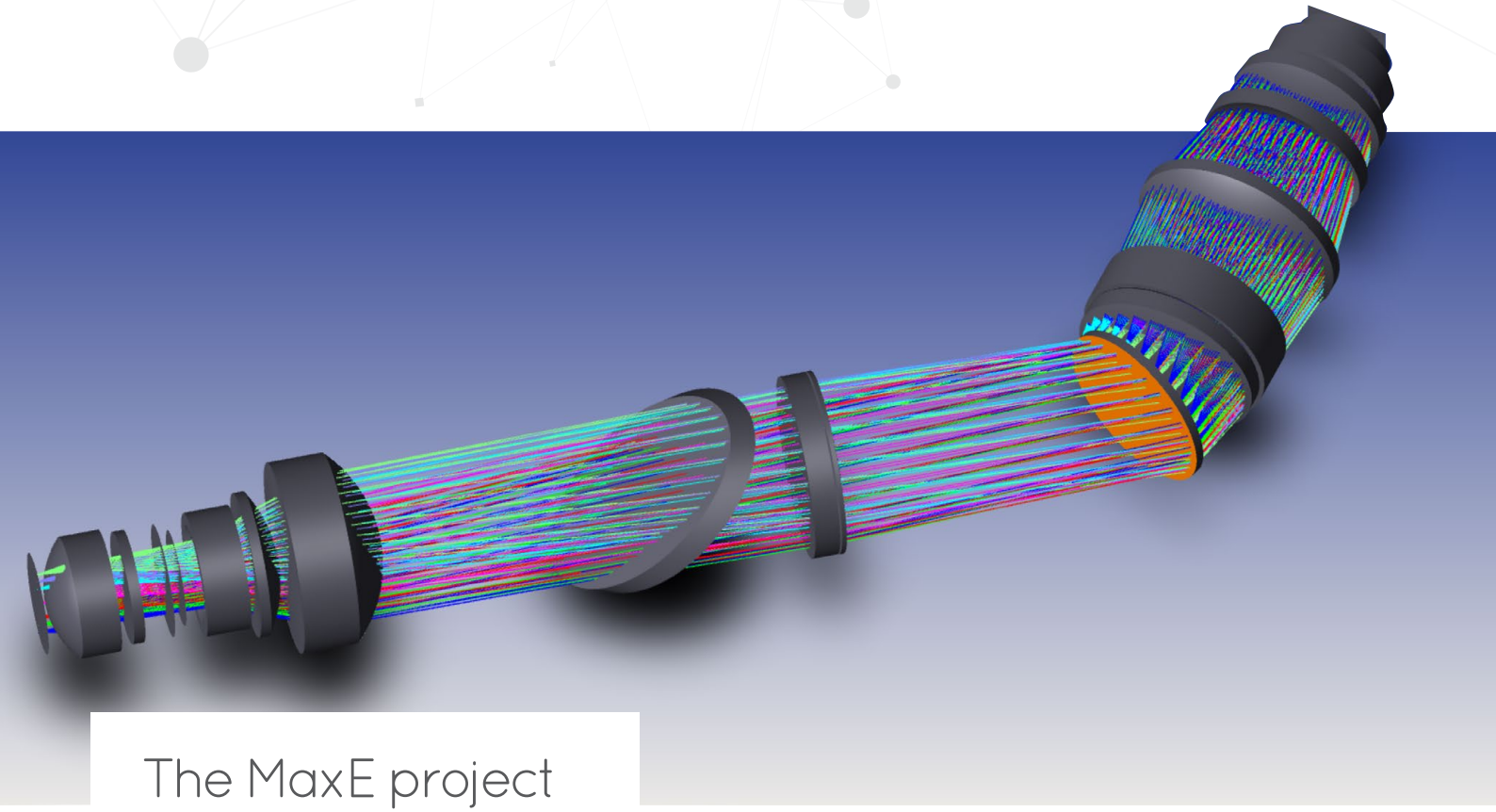
Lesedi

SAAO is in the final stages of commissioning a 1-metre, alt-az telescope for use by the local and international astronomical community. The telescope has been named Lesedi – meaning light or enlightenment in Sesotho and Setswana – a name selected from entries submitted in a nationwide schools' competition. The telescope will be available through observing proposals offering the traditional week-long blocks as well as shorter service applications, and can be operated remotely from Cape Town as well as locally at Sutherland.

Lesedi has two identical Nasmyth foci, with high throughput down to ultraviolet wavelengths. The instrument currently mounted on the telescope is one of SAAO's high-speed cameras, SHOC (Sutherland High-speed Optical Camera), with UBVRI and clear filters, and a field-of-view (FOV) of 5.7 × 5.7 arcminutes. A new, custom-made camera – designed and built at SAAO – will fully exploit the telescope's 43-arcminute diameter field-of-view (the largest of any of our SAAO telescopes) and is soon to be commissioned. To complete the instrument suite, a low-resolution spectrograph (R~350) is being built, and an echelle spectrograph (R~79,000) is in the design phase. All four instruments will be permanently mounted: the wide-field camera on one Nasmyth focus, and on the other Nasmyth, the low-resolution spectrograph with SHOC doubling up as its detector, and a fibre-feed to the echelle. This will allow instantaneous switching of instruments, which is ideal especially for transient science/research.



Nasmyth focus	f/8, 25.8 arcsec/mm
Field of view	43 arcminute diameter
Current Instrumentation	SHOC (UBVRI+clear filters) – FOV: 5.7×5.7 arcmin
Future Instrumentation	Sibonise (imaging camera) – FOV: ~40×40 arcmin Low-resolution spectrograph (R~350) High-resolution spectrograph (R~79,000)
Accessories	Autoguider on each Nasmyth port



The MaxE project

As part of the SALT Generation 1.5 instrumentation package, a high-efficiency spectrograph is to be designed and built over the next two and a half years. The new maximum-efficiency spectrograph (MaxE) will support the SALT strategic plan by accommodating the expected increase in transient science (based on triggers coming from MeerKAT and LSST, among others). The MaxE project has kicked off in January 2019 as part of the NRF/SALT Strategic Instrumentation Initiative, with a number of newly hired people and some seconded from SARAO joining the team. Both the optical design of the spectrograph and the detector package will be developed in-house to leverage SAAO's existing instrument building capacity and expertise. The project will also create additional capacity within the SAAO Instrumentation group to support the development of future instrumentation for SALT as well as for other observatories.

The aim of the project is to build a simple, efficient, broad-band, low-resolution spectrograph. The concept sees SALT's Robert Stobie Spectrograph (RSS) turned into a dual-beam spectrograph by building an additional optical (red) arm, with the existing RSS spectrograph serving as the MaxE blue arm. The fold mirror will be replaced by an interchangeable dichroic/fold mirror, so that with the fold mirror in place, all the existing capabilities of RSS will still be available. The new red arm will then be incorporated where the NIR arm was originally intended to be, sharing the existing RSS field lens and collimator main group. The new dual-beam RSS will cover the bandpass 360 to 900 nm simultaneously, at a resolving power of roughly 900 in the blue and roughly 2000 in the red. For science cases other than classification spectroscopy, this also opens up many interesting options involving any existing grating in the blue arm and different exposure times in the two arms.

Top: Conceptual design image for MaxE.

Above: SALT at Sutherland

OUTREACH & EDUCATION

The NSTF Brilliants Awardees visit SAAOs' McClean telescope.

For SAAO, science engagement continues to be an important part of not only highlighting the work done at the organisation, but as a tool to promote the importance of science. In addition to being a research facility, SAAO prides itself in the outreach activities that it hosts as a way of connecting and engaging with learners and members of the general public. SAAO reaches out to thousands of them by, for example, hosting school groups, offering visitors a look at the telescopes in Sutherland or by inviting members of the public to Cape Town where Open Nights are held twice a month. The activities provided at such engagements are designed to be both educational as well as fun for science enthusiasts, with hopes of creating a more 'astronomy' aware audience across the country and beyond. Furthermore, SAAO has a host of educational resources on its website, particularly aimed at educating learners from as young as grade R, through animations of indigenous African stories, astronomy facts and quizzes, and astronomy related puzzles.

Student visits

SAAO reaches out to thousands of learners every year, with the goal of teaching them more about science in general and astronomy in particular. We frequently visit schools, but we also invite school groups to SAAO. These are usually learners from grade R to grade 12, but college and university students are welcome, too. We have dedicated staff members who entertain the students with various exciting activities such as Solar system presentations, binocular workshops, star gazing nights, site tours, and day and night tours in Sutherland. The snapshots to the right show some of the visits we had from schools in the last financial year.


Zisukhanyo High School, 24 January 2019


Niko Brummer Primary, 25 & 26 May 2018


Heideveld Primary, 25 July 2018


Park Primary School, 2 September 2018


Cannons Creek Primary School,
18 September 2018


Sid G. Primary School, 25 September 2018


Rustenburg Girls Junior School,
25 September 2018

Curro Century City,
20 & 21 November 2018


Touwsriver Primary, 15 February 2019


Cape Academy, 15 & 16 February 2019


Entshona Primary School, 27 February 2019


Soneike High School, 7 April 2019

Educator workshops

As part of our outreach, SAAO provides various workshops for teachers. These workshops focus on a number of subject matters within science with the aim of providing a curriculum for science teachers that better equips them to pass on their knowledge to students and learners. These workshops consists of presentations of "matter and material", astronomy, and telescope and binoculars. Furthermore, the curriculum workshops are aimed at advising teachers on how to assist learners with science concepts and models.

KZN Teacher workshop, 28 May

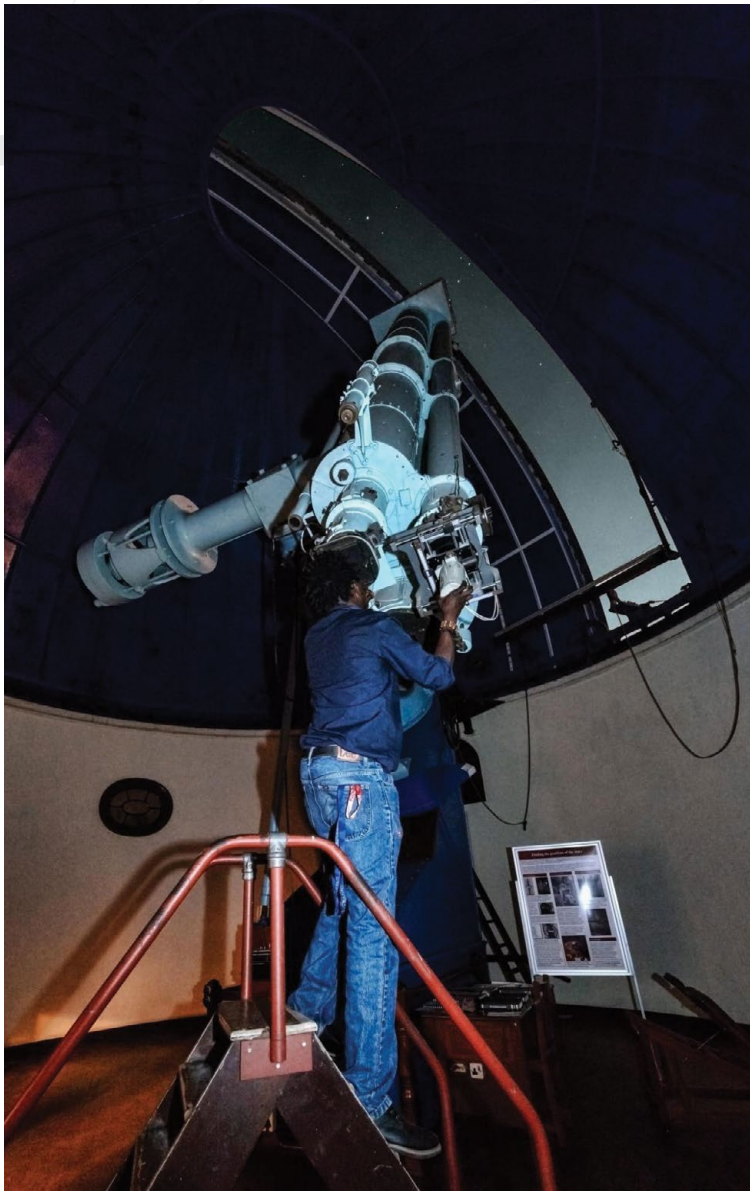
KZN Teacher workshop, 1 June 2018

Northern Cape Educator Workshops, 18 – 20 July 2018

KZN Teacher workshops, 10 – 14 September 2018

Limpopo Teacher workshops, 18 – 21 September 2018

UCT Student Teacher Workshop, 3 October 2018



Reaching out to the public

SAAO's Open Nights are held twice a month on a Saturday and include a public lecture, a star gazing session and a visit to the SAAO museum. The lectures are mostly held by South African astronomers, but occasionally a visitor from overseas talks about the latest of their exciting research. The South African government has identified the Northern Cape as the Astronomy Hub of South Africa, and the Sutherland site attracts a large number of visitors including overseas tourists. The Observatory at Sutherland has a Visitor's centre and offers tours of selected telescopes. The majority of the public, however, is reached through science expos and festivals across South Africa where they can talk to SAAO staff members and ask questions relating to science in general and astronomy in particular. Many of the questions, in fact, relate to South Africa's two world-class telescopes: the optical SALT and the radio telescope array MeerKAT.

Outreach highlights

The event had been the longest total lunar eclipse of the 21st century so far.

Lunar eclipse viewing

During the evening of Friday, 27 July 2018, one of nature's most impressive spectacles was on display across Southern Africa as the full Moon slipped into the Earth's shadow, resulting in a total lunar eclipse. Professional astronomers from SAAO alongside members of the Astronomical Society of Southern Africa (ASSA; an association of amateur astronomers) offered the public a free viewing with an array of telescopes along the V&A Waterfront in Cape Town. The evening's observing programme began at sunset (18:00) with a tour of the Solar system with numerous instruments as large as 25 cm in diameter. The planets Venus, Jupiter, Saturn and Mars were visible for telescopic viewing. The full Moon began to darken as it entered the Earth's shadow at 19:15, with totality beginning at 21:30. The total eclipse lasted nearly two hours. Also without any visual aide, the sight of the Moon in total eclipse was striking.

The event had been the longest total lunar eclipse of the 21st century so far. In addition, Mars was at its brightest for many years: Mars, the Earth, and the Sun were roughly lined up on 27 July 2018, with the Moon just passing through for a couple of hours. Mars being on the opposite side of the Earth to the Sun is known as opposition, meaning the planet is near its closest point to Earth. On Friday night, Mars was even closer than usual (being near its perihelion), about 57.7 million kilometers away from Earth. This also meant that Mars was nearly its largest apparent size possible and was close to its maximum apparent brightness.

The girl learners visiting the SALT telescope.

Bring a girl child to work

Founded by Vulombe Mulaudzi from the SALT Collateral Benefit Programme, the "Bring a Girl Child to Work" is an initiative which promotes independence and perspective into different careers in the working field to young girls. The 2018 programme selected 14 girls in grades 8 to 11 at Sutherland High School, based on their overall performance in class and their attitude towards life. Some of the girls serve on local community boards, such as Youth Against Crime and Junior Station Commissions. During their time at the observatory they interacted with astronomers, engineers, technicians, IT specialists and administrative and outreach staff. Positive feedback was given by the participants and the programme will be continued to run quarterly.

Astronomy Quiz

The astronomy quiz is an initiative created to educate learners about astronomy in exciting ways while incorporating a positive competition atmosphere between learners from various schools.

This year's event was organised by B. Khumali with assistance from C. Hetlagge and C. Jacobs, and 613 learners from the Western Cape province and 320 learners from Northern Cape province participated.

Winners of the quiz were Park Laerskool from the Western Cape and Postmasburg Primary School in the Northern Cape. The former visited the Sutherland Observatory as part of t heir price.

SciFest2019

Science festivals are one of the many ways for SAAO to participate in the bid to educate learners and the general public in astronomy. Every year, a team from SAAO tries to find new ways of generating interest in learners and the general public through their intriguing exhibitions. On 6 March 2019, a team of six SAAO employees (Sivuyile Mangxoyi, Christian Hettlage, Anthony Mietas, Cedric Jacobs, Pranesthan Govender, Daniel Cunnama) headed out to Grahamstown to represent SAAO at the SciFest2019. The team's activities consisted of astronomy-related workshops throughout the day and of public lectures which referred specifically to the future of astronomy in South Africa. Along with the exhibition stall, SAAO had a photo booth which was most popular. Also popular were iPads which contained an astronomy quiz: learners were awarded certificates for answering a minimum of 10 out of 15 answers correctly. At the SciFest2019 prize-giving ceremony SAAO carried away the day: the team was awarded "Highly Commended" for their exhibition stall, which was the highest award of all. The excited team is already discussing new ideas for SciFest2020.

Festival Curator Dr Stephen Ashworth awarded the NRF/ SAAO team for winning `Best Exhibition' in the `Highly Commended' category of the SciFest Africa awards. With him are (from left to right): Sivuyile Manxoyi, Pranesthan Govender and Christian Hettlage.

Job shadowing

Two job shadowing sessions were held at SAAO during school vacations, with 23 learners in total, drawn from various high schools. The programme also highlights related careers and the roles they play in the field of astronomy: software developers, IT staff, engineers, education and outreach personnel. The two-day intensive programme exposes learners to the experiences of observers as well as theorists; it introduces them to the continuation of observation and data collection through data analysis to interpretation. The learners are also supplied with information on the various institutions of higher learning that offer relevant courses, as well as where and when to apply for bursaries and scholarships.

National Science Week
(30 July –3 August 2018)

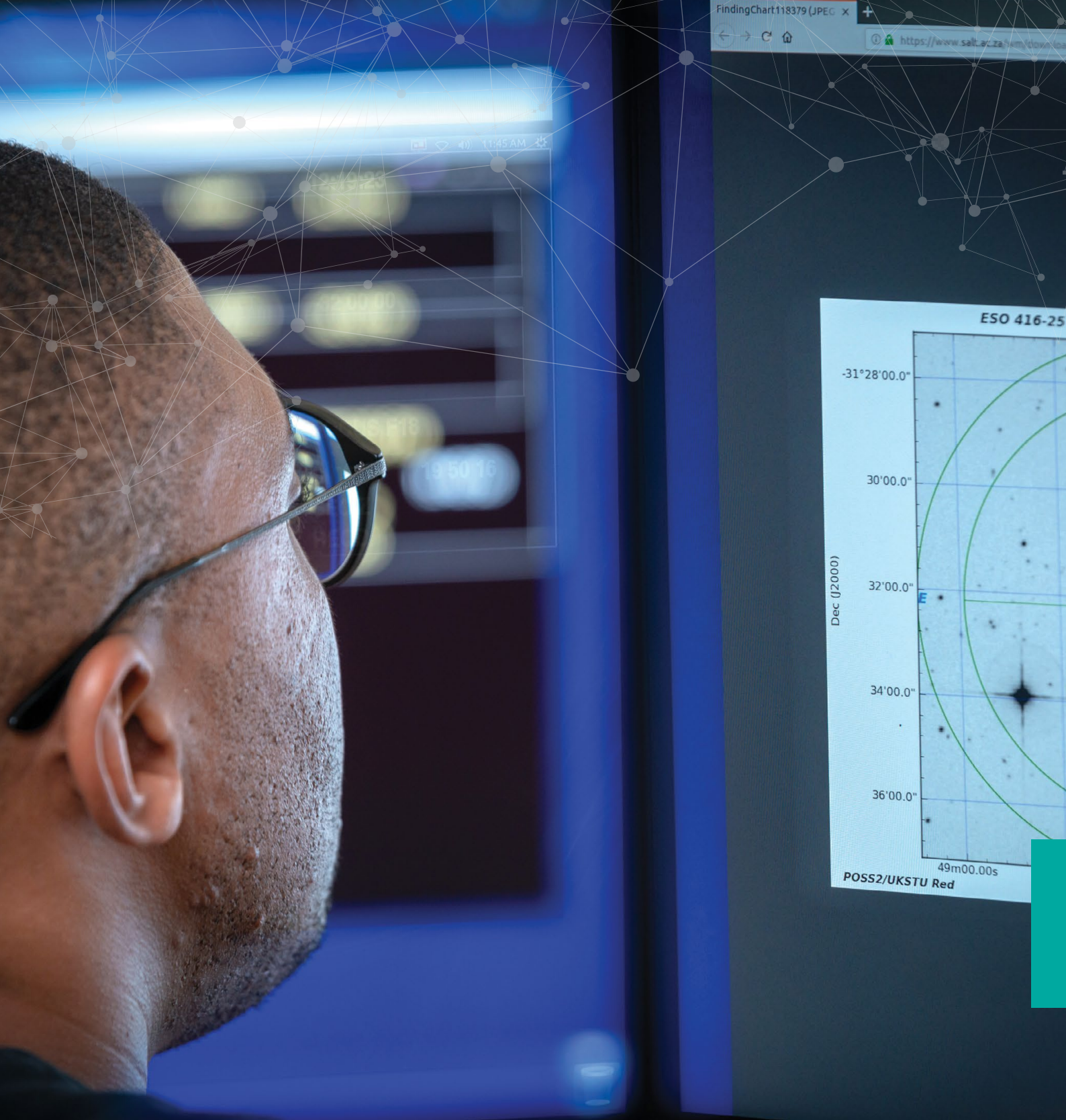
South Africa dedicates the first week of August of every year to celebrate the achievements of science and technology. The week is used to inspire learners and students to decide on science-based studies and to inform the general public about the advances made by science and technology in South Africa. Astronomy and space science are usually the main themes – which gives SAAO the opportunity to be more involved in the activities whilst promoting astronomy. From 30 July 2018 to 3 August 2018, Buzani Khumalo and Cedric Jacobs held telescope workshops and solar system and stellarium presentations for learners across the Western Cape. Close to 800 learners were reached during this week and their enthusiasm to learn made the events a happy and exciting atmosphere.

Snapshots of National Science Week

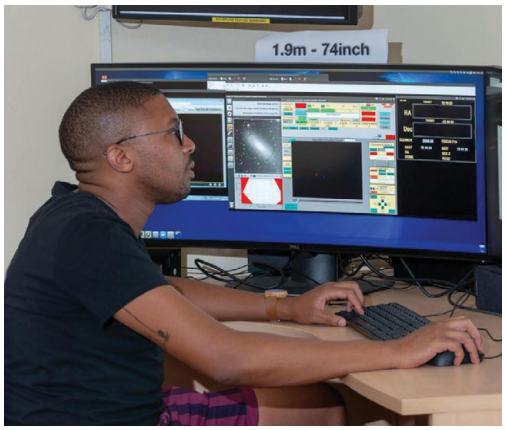
NSTF Brilliants tour

In partnership with SARAO and the National Science and Technology Forum (NSTF), SAAO hosted the NSTF Brilliants Astronomy tour from 21 – 27 June 2018. The NSTF Brilliants programme recognises the top female and male learner, chosen from each of the nine provinces, based on their marks in mathematics and physical science in the previous year's National Senior Certificate Examinations (grade 12). The astronomy tour saw the Brilliants Awardees visit four provinces, SAAO and Iziko Planetarium in Cape Town, SALT, the radio telescopes KAT-7 and MeerKAT outside Carnarvon and the Hartebeesthoek Radio Astronomy Observatory outside Johannesburg.

The tour ended with a Gala Dinner for the 20th annual NSTF–South32 Awards at Emperors Palace in Johannesburg in which the Brilliant students were honoured and various other awards for science excellence were given. The awards were presented by the Minister of Science and Technology, Ms Mmamoloko Kubayi–Ngubane, who is the event's patron. The event was attended by almost 700 guests and over 50 different organisations from the broader community. SAAO's SCBP manager, Sivuyile Manxoyi, had been one of the nominees for the Communication Award for outreach and creating awareness.



STAFF HIGHLIGHTS



Itumeleng Monageng's invitation to the Lindau Nobel Laureate meeting

On 4 March 2019, the Academy of Science of South Africa (ASSAf) announced that one of our scientists, Itumeleng Monageng, who obtained his PhD at the University of Cape Town in 2018, was selected as one of the top 20 young scientists from South Africa to attend the prestigious Lindau Nobel Laureate meeting in Germany in July 2019. These meetings take place every year in Lindau, Germany, where 30 – 40 Nobel Laureates meet outstanding young scientists aged up to 35: undergraduates, PhD students, and post-doc researchers. The scientific programme is based on the principle of dialogue: lectures, discussions, Master classes, and panel discussions are specially designed to facilitate the exchange of knowledge, ideas, and experience between the Nobel Laureates and the young scientists. A multi-step application and demanding selection process ensures that only the best young scientist are selected. Monageng was selected as one of the top 20 young scientists from South Africa and one of 580 young scientists from 88 countries to attend the 2019 meeting.

Freddie Marang's story on CNN: 40 years at SAAO

Freddie Marang, a telescope operator of SALT, was featured on CNN on Friday, 26 April 2019, and throughout that weekend. Freddie's story was broadcasted as part of the CNN International African Voices shown around the world, highlighting his impeccable 40 years of service at the SAAO.

Freddie was appointed as the first telescope 'Night Assistant' at Sutherland in 1978 after he was laid-off from work in a television manufacturing company. Married to a woman from Sutherland, he decided to go to Sutherland and apply at the Observatory for work. Two weeks later he received a telegram inviting him for an interview. After his interview, having impressed his interviewers with his knowledge, he received a second telegram offering him a job as Night Assistant which allowed him to officially move to Sutherland.

His duties as a night assistant included assisting telescope observers and to prepare and develop photographic plates. After a few years, Fred was promoted to doing observations on his own – a task he really enjoyed – with the 1.9-m telescope being the first telescope he learned to drive. In 1993, Fred made an exciting discovery about an eclipsing binary and in 2005 he was trained as one of the first SALT operators. He has co-authored 111 peer-reviewed papers. Now, at age 65, Freddie is still with SAAO, and although he is due to retire soon, he believes he still has mileage in him and will thus do everything he can to continue to contribute in his field.

Freddie's story is available on the SAAO Youtube Channel.

Retha Pretorius awarded a Newton Advanced Fellowship

Retha Pretorius, together with Christian Knigge from the University of Southampton, was awarded a Newton Advanced Fellowship grant of about R1.8 million. In sharing the great news with the SAAO staff on the internal newsletter, this is what she wrote:

"The worst thing about being a scientist is probably having to write grant applications. I'm sure none of us enjoys having to come up with the self-promoting, cringeworthy stuff that goes into these proposals, and of course chances are you get nothing in return. But now and again you can also get lucky.

"I was recently awarded a Newton Advanced Fellowship to support my collaboration with Christian Knigge at the University of Southampton. The grant is worth about R1.8 million, to be spent over 3 years on things such as equipment, conferences, and travel between Cape Town and Southampton, for me, Christian, and students. Christian is a fantastic researcher and teacher, so it will be great to have him spend some time here. I also think it will be wonderful for some SAAO students to visit Southampton to do part of their research work in the strong astronomy group over there.

"We're facing a tough research funding climate in South Africa at the moment, so it makes sense to search out international opportunities. The Newton Fund aims, amongst other things, to develop research collaborations between the United Kingdom and several partner countries. Their science-related grants are run by the Royal Society, and there are several types available. Definitely worth a look!"

"We're facing a tough research funding climate in South Africa at the moment, so it makes sense to search out international opportunities" – Retha Pretorius

Daniel Cunnama on "The Final Frontier"

Our Science Engagement astronomer, Daniel Cunnama, makes regular appearances on the Expresso show which airs every morning on weekdays at SABC 3 in a science-related segment called "The Final Frontier". This segment is aimed at unravelling science-related topics and educating the general public and science enthusiast about the latest discoveries. Astronomy is one of the most frequently discussed themes, and Daniel (better known as Space-man Dan on the show), is usually one of the most featured South African astronomers on the show discussing South African and international scientific advances.

Patricia Whitelock awarded the SAIP De Beers Gold Medal 2018

Professor Patricia Ann Whitelock, one of SAAO's long-standing researchers, was awarded the SAIP 2018 Gold Medal for her outstanding research career in astronomy and astrophysics, and for her distinguished and extensive contributions to leadership, education and human capacity development of the Physics and Astronomy community.

Whitelock is an NRF A-rated researcher who has authored and co-authored over 190 peer-reviewed journal articles over her career. Her research is focused on our understanding of the late stages of stellar evolution and mass-loss of evolved stars, the structure of the Milky Way galaxy, and the stellar content of the local group galaxies. Her scientific work has been cited over 8000 times.

During Whitelock's career, she has held various important positions. She served as deputy director, acting director, and director of SAAO. She also served on the NRF executive from 1998 to 2003. She is the chair of the Scientific Council of the Strasbourg Astronomical Data Centre (CDS) and is a member of two executive committee working groups of the IAU: the Global Coordination of Ground and Space Astrophysics WG and Women in Astronomy.

Whitelock's contribution to the development of the astronomical community in South Africa are extensive. She helped to establish the National Astrophysics and Space Science Program (NASSP) where she served as the first chair of its steering committee between 2002 and 2013. She was also one of the key drivers behind the successful bid by South Africa to host the international Office of Astronomy for Development (OAD) of the IAU. She served on its founding steering committee and currently serves on the steering committee of Southern African Regional OAD.

By awarding the 2018 SAIP Gold Medal to Prof. Whitelock, the SAIP bestows onto her the greatest distinction that is conferred in South Africa for achievements in Physics.

SAAO STUDENTS

Graduated students

Estimates of the distance and measurements of the line velocities suggest that the nova might be associated with the Sagittarius stream. If so, it would be the first nova to be discovered in a dwarf spheroidal galaxy.

Elias Aydi, *PhD, UCT*

Title: Multiwavelength studies of classical novae
Supervisors: Dr Shazrene Mohamed (SAAO) and Prof. Patricia Whitelock (SAAO/UCT)

Abstract:
Classical novae are transient astronomical events resulting from an eruption on the surface of an accreting white dwarf in interacting binary stars, namely cataclysmic variables. These eruptions and their progenitors are ideal astronomical events/objects to study a variety of interesting topics, such as mass-transfer mechanisms, binary evolution, and thermonuclear and radiative emission processes. Novae share some general observational characteristics during their eruption phases, yet each nova is new and can show unique light-curve and spectral developments. Therefore, carrying out detailed multiwavelength studies of individual novae is important to provide an holistic picture of the eruption development with the ultimate aim of a general understanding of the physical mechanisms involved in nova eruptions, as well as the structure and evolutionary condition of their progenitors. This dissertation presents detailed multiwavelength studies of three nova events, namely V5852 Sgr, SMCN 2016-10, and V407 Lup, as a series of chapters (papers).

Our data were collected using several ground-based and space telescopes including: high- and medium-resolution optical spectroscopy from SALT, SOAR, and FLOYDS, optical and near-infrared photometry from IRSF, OGLE and SMARTS, UV and X-ray data from Swift, Chandra, and XMM-Newton. In the second chapter, we present an optical and infrared study of the unusual nova V5852 Sgr. This nova is a moderately fast nova showing features of the Fe II spectroscopic type. The light-curve development is unique, showing a combination of several light-curve classes. Estimates of the distance and measurements of the line velocities suggest that the nova might be associated with the Sagittarius stream. If so, it would be the first nova to be discovered in a dwarf spheroidal galaxy. The third chapter presents a multiwavelength study of the very fast nova SMCN 2016-10a. The fast light-curve development suggests that the system hosts a massive white dwarf (≥ 1.25 $M_{\odot}$), in good agreement with the high temperature of the super-soft X-ray emission and the turn-on/turn-off time of the super-soft state. At the distance of the Small Magellanic Cloud our measurements suggest that SMCN 2016-10a is the brightest nova in the Small Magellanic Cloud and one of the brightest novae on record, with an absolute maximum magnitude of ~ -10.5 in the V-band. Chapter four is a multiwavelength study of nova V407 Lup. With a light-curve decline time t_2 ≤ 2.9 d, this is one of the fastest known examples and the white dwarf is possibly more massive than 1.25 $M_{\odot}$. Our set of optical, UV, and X-ray data suggest that this system is an intermediate-polar cataclysmic variable based essentially on the presence of two periodicities (3.57 h and 565 s) in the light-curves. These periodicities are attributed to the orbital period of the binary and rotational period of the white dwarf. The late optical spectra (taken from day 165 post-eruption) show narrow and moving lines of He II and O VI, possibly associated with accretion regions within the binary system. This, along with the X-ray light-curves and spectra, suggest that the accretion probably resumed around 168 days post-eruption.

These studies are modest, yet essential steps in the quest for a better understanding of nova eruptions. They also demonstrate the importance of multiwavelength follow-up of novae for constraining the physical parameters of the eruption, the ejecta, and the properties of the progenitor. In the era of large all-sky surveys, such as the All-Sky Automated Survey for Supernovae and eventually the Large Synoptic Survey Telescope which have been and are ex- pected to find a large number of optical transients and classical novae, similar multiwavelength follow-up will play a crucial role for initially identifying these transient events and further understanding their physical behaviour.

Future 21cm observations provide tighter constraints on the astrophysical parameters and complement different derived constraints from other reionization observations.

Sultan Hassan, *PhD, UWC*

Title: Simulating the neutral hydrogen distribution during cosmic reionization
Supervisor: Prof. Romeel Davé (SAAO/UWC)

Abstract:
We improve on the physical treatment of ionising source and sink populations in the large scale semi-numerical simulations by implementing new physically motivated parametrizations taken from high-resolution radiative transfer simulations, in order to account for the non-linear dependence on halo mass, redshift and environment. This provides an efficient unique way to connect the small scale astrophysics to the large scale cosmology. These new parametrizations allow the model to simultaneously match all current reionization observations with only 4% photon escape fraction.

These improvements result in 2–3 x 21cm power spectrum variations on small and large scales, and hence showing the importance of accurately treating ionising sources and sinks in 21cm simulations. We further implement time-integrated effects to accurately track the evolution of ionising photons, inhomogeneous recombinations and partially ionized regions during reionization. Including these effects yields larger HII regions and a more sudden reionization, which leads to an order of magnitude more 21cm power on large scales. We develop a robust parameter estimation pipeline to constrain the model astrophysical parameters against several reionization observations. We find that future 21cm observations provide tighter constraints on the astrophysical parameters and complement different derived constraints from other reionization observations.

We finally employ the high redshift observations to add ionising photons from Active Galactic Nuclei (AGN), in order to assess the ability of AGN-dominated models to solely complete reionization. Unlike the case with galaxies, the AGN-only models cannot simultaneously match all current reionization observations. AGN-only models produce 21cm power spectrum that is 2 x higher on all scales as compared with galaxies-dominated models. Future 21cm surveys will play a key role to distinguishing between these two scenarios, even though AGN are highly unlikely to drive cosmic reionization.

Itumeleng Monageng, *PhD, UCT*

Title: Optical and gamma-ray study of gamma-ray binaries
Supervisors: Dr Vanessa McBride (OAD-SAAO/UCT), Prof. Markus Böttcher (NWU) and Dr Shazrene Mohamed (SAAO)

Abstract:
X-ray binary stars are fascinating objects that provide an opportunity to study extreme astrophysical conditions. A small population of X-ray binary systems, namely gamma-ray binaries, consisting of only six confirmed sources, exhibits multiwavelength emission observed from the radio to the VHE gamma-ray regime. The focus of this thesis is the optical and gamma-ray emission of gamma-ray binaries.

We present optical spectroscopic analysis of 1FGL J10185856 with the Southern African Large Telescope, where we perform radial velocity measurements using blue spectra of the O star in this system. The extensive orbital phase coverage from our observations, together with measurements obtained from literature allows for constraints to be placed on the orbital parameters. We derive, for the first time, the orbital eccentricity of 1FGL J10185856 which, along with the other parameters, enables us to decipher the orbital geometry of the system. Furthermore, the mass function obtained allows us to constrain the mass of the compact object. We find that a neutron star is favoured for a large range of allowed orbital inclination angles, in agreement with previous inferences from literature, although a black hole is not completely excluded provided that the inclination angle is very small.

We have also explored long-term variability of the circumstellar disc in LS I +61 303 through the analysis of the H-alpha emission line. We present analysis of measurements of different features of the H-alpha line and evaluate these using a semi-analytical model which describes the motions of particles in Keplerian orbits. In this work, we demonstrate that several different parameters describing the geometry of the disc vary on timescales comparable to the superorbital period of the system. The work also shows, for the first time, observational signatures of the Kozai-Lidov mechanism in hydrodynamical discs through the evaluation of eccentricity changes of the disc.

A study of high energy emission processes in gamma-ray binaries is presented. We have explored the Bethe-Heitler mechanism for the production of gamma-ray emission, where energetic protons collide with stellar photons to produce energetic electron-positron pairs which upscatter photons to high energies. We show calculations of the spectrum and modulated flux in the context of the pulsar wind scenario, with photon-photon absorption and cascading effects taken into account. The effects of the ambient magnetic field around the massive star are shown, which result in quasi-isotropic gamma-ray emission, and the orbital modulation of the flux resulting in photon-photon absorption.

We find that a neutron star is favoured for a large range of allowed orbital inclination angles, in agreement with previous inferences from literature, although a black hole is not completely excluded provided that the inclination angle is very small.

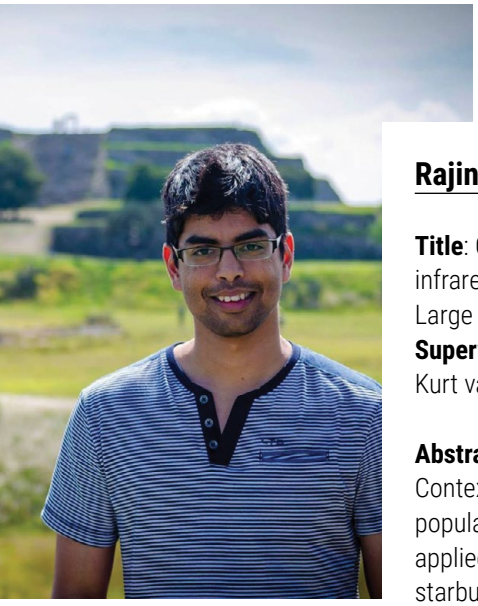
Mika Rafieferantsoa, *PhD, UWC*

Title: Neutral hydrogen in galaxies, its content and the effect of environment on its evolution
Supervisor: Prof. Romeel Davé (SAAO/UWC)

Abstract:
Using two hydrodynamic galaxy formation simulations from the Mufasa project that I helped develop, we aim to better understand the relationship between galaxy evolution and its cold gas content commonly known as the neutral hydrogen or HI. We first look at the environmental properties of the simulated galaxies and compare to those that are available observationally. As a proxy, we specifically quantify the so-called galactic conformity, which is the concordance between the properties of galaxies neighbouring the primaries, in chapter 2. We show that the HI, the specific star formation rate (sSFR) and the colour of galaxies show galactic conformity in qualitative agreement with previous observed data, i.e. the HI-rich primary galaxies are surrounded by HI-richer galaxies than the HI-poor primary galaxies, and similarly for the sSFR and the colour. We find that environment, quantified by the number of neighbouring galaxies within a fixed aperture, stellar age and molecular hydrogen (H_2) also show conformity. Galactic conformity also depends on the dark matter halo mass of the primary galaxy. The galactic conformity signal from the primaries of smaller haloes is weak but extends out to several virial radii of those structures, whereas the signal is very strong for high mass haloes but lowers quickly with distances from the primaries. We also find the galactic conformity only emerges in the later half of cosmic evolution.

We next quantify the gas content and star formation depletion timescales in chapter 3. We use two carefully chosen groups of simulated galaxies and find that timescales are affected by both the mass of the virialised structure of the first infall and the galaxy stellar mass at infall: the higher the halo mass or the stellar mass the shorter the timescale. The gas or HI depletion timescale is concordant to that of the star formation quenching, indicative of direct decrease of SFR due to depletion of the extended cold gas reservoir. The neutral atomic or molecular hydrogen consumption timescale depends on the Hubble time. Galaxies tend to form stars more efficiently at lower redshift. While the halo mass of infall affects the consumption timescale of the HI, it does not correlate with the H_2.

We lastly develop machine learning tools to use galaxy photometric data to predict a galaxy's HI mass in chapter 4, to allow predictions for HI from much larger optical photometric surveys. The training and testing of the algorithms are done first with the simulated data from Mufasa. We show that our model performs better than previously done with ad hoc data fitting approaches. Random Forest (RF) followed by the Deep Neural Networks (DNN) perform best among the explored machine learning techniques. Extending the trained models to observed data, namely the Arecibo Legacy Fast ALFA (ALFALFA) and REsolved Spectroscopy Of a Local VolumE (RESOLVE) survey data, we show the overall performance is slightly reduced relative to the simulated testing set owing to the small inconsistency between definition of galaxy properties between simulation and observational data, and DNN performs the best in this case. The application of our methods is useful for galaxy-by-galaxy predictions and anticipated to correct for incompleteness in the upcoming HI deep surveys done with MeerKAT and eventually the Square Kilometre Array (SKA).



Rajin Ramphul, *PhD, UCT*

Title: Characterising star forming and luminous infrared galaxies with the Southern African Large Telescope (SALT)
Supervisors: Prof. Petri Väisänen (SAAO), Dr Kurt van der Heyden (UCT)

Abstract:
Context: Stellar population modelling is a popular technique that has been extensively applied to main sequence galaxies. Yet starburst galaxies and Luminous InfraRed Galaxies (LIRGs) have, so far, not been studied as much using the method. LIRGs in the local universe are known to be highly interacting galaxies with strong star formation in obscured environments. Still, LIRGs also have diversity in terms of morphology and mode and location of star formation.

Aim: This thesis investigates the stellar population properties of a group of 52 starbursts and luminous infrared galaxies (LIRGs) in the local universe that forms part of the SUperNovae and starBurst in the InfraReD (SUNBIRD) survey. The galaxies in a distance range of $3.5 < D_l < 280$ Mpc and infrared luminosity of $10.30 < L_{IR} < 11.91$ L_{solar} were observed with the Southern African Large Telescope in long-slit spectroscopy mode.

Method: The stellar populations of the galaxies are derived by fitting Bruzual & Charlot (2003) templates to the reduced spectra using STARLIGHT software with a Monte Carlo method implemented to recover uncertainties on age, metallicity and extinction. The derived stellar population models are then subtracted from
the observed spectra to produce emission spectra from which emission line fluxes are measured. Both integrated spectra and spatially resolved apertures are extracted to be analysed in this work.

Results: The light-weighted and mass weighted age of the sample is found to be 160 Myr and 7.2 Gyr respectively. The star formation history of the sample shows a rise of activity in the past 50 Myr and with a jump of an order of magnitude in the past 3 Myr. Analysis of the stellar metallicity hints at inflow of pristine gas, which decreases the observed metallicity content as well as ignites SF-activity. Analysis of the oxygen abundances shows that while LIRGs and SF galaxies are under abundant, their under-abundance may have previously been over-estimated as compared to main sequence galaxies.

The radial age profile of the sample is flat, similar to that of late-type Sd galaxies. Interaction is found to cause a drop in the age of apertures although the post-merging stages shows continued star forming activity in the nuclear region. The stellar metallicity gradient is found to be −0.029 ± 0.018 dex/kpc, comparable to Sb or Sbc galaxies favouring an inside-out formation scenario for the galaxies. As interaction stage increases, both age and metallicity gradients are seen to get flatter, eventually getting slightly positive. The more active interaction stages are HII driven, while isolated and post merging stages shows higher AGN activity.

The current work offers an update on the abundances of IR dominated galaxies from the previous work done by Rupke et al. (2008). The formation scenario of our LIRGs in the local universe is shown to be in line with the scenario put forward by Hopkins et al. (2008). Future works with medium resolution spectra acquired during the course of this thesis should allow for detection of gas inflows and better constrain the different ionising mechanisms involved at different interaction stages.

The star formation history of the sample shows a rise of activity in the past 50 Myr and with a jump of an order of magnitude in the past 3 Myr.

Anja Genade, *MSc, UCT*

Title: Stellar occultations by bodies in the outer solar system at the South African Astronomical Observatory
Supervisor: Dr Amanda Sickafoose (SAAO) and Dr Shazrene Mohamed (SAAO/UCT)

Abstract:
Information on the origin and evolutionary processes of the Solar System is harbored by primitive bodies called trans-Neptunian objects (TNOs). Their preserved state is due to these bodies having orbits at and beyond that of Nep-tune, as this specific area is considered to be the least thermally modified in the Solar System and could contain a large population of primordial remnants.These archaic remnants not only provide us with information on our infant Solar System, but also improve our understanding of extrasolar planetary formation processes. Stellar occultations by TNOs enable the determination of sizes and shapes with kilometric accuracy (confining albedos, leading us to compositions and densities), the detection of atmospheres down to pressures of a few nano-bars, as well as an investigation of the immediate vicinity of the target body (indicating the presence of rings, satellites, jets, comas). These TNOs roam the icy outskirts of our Solar System which make them faint and their stellar occul-tations short-lived. With a duration ranging from a couple of seconds for small bodies up to a few hundreds of seconds for the larger TNOs, specific imaging cameras combined with Global Positioning devices and optical telescopes, ensure the fast-cadence capture of these events with microsecond timing accuracy.The accuracy of stellar occultation results is only rivaled by measurements taken from space probes.

Here, we present work done by the South African Astronomical Observatory (SAAO) stellar occultation observing programme during the period of July 2016–July 2017. Specifically, we describe the telescopes, instruments and data analysis pipelines that are used for the SAAO stellar occultation program. The stellar occultation results are obtained from the slightly modified, data reducing SHOC pipeline as originally developed by Dr. Marissa Kotze. The SHOC pipeline laid the groundwork for two additional pipelines to be developed and therefore the MORIS instrument on the 3-m IRTF as well as the FLI autoguider cameras mounted on multiple 1-m LCO telescopes are included to provide many opportunities to observe the predicted stellar occultations. These pipelines include reduction features, correct and accurate derivation of timing information, optimization of the signal-to-noise ratio (SNR) through aperture corrected pho-tometry and most important, provide the user with light curve plots of the point sources. The light curves are normalized and individually analyzed for any signs of a positive stellar occultation detection while testing the effects of reduction on the SNR. This is followed by checking the statistical distribution of the data as well as determining a few values for the line-of-sight optical depth. Instrumental deadtimes for the LCO guider cameras are calculated to effectively determine and use time allocated through proposals.

Finally, a single positive stellar occultation by Orcus was observed on 7 March 2017 from two separate sites. Here, chord length calculations as well as timing offsets are calculated from the normalized light curves which led to a possible detection of both Orcus and Orcus's satellite, Vanth. An in depth discussion is provided to justify this reasoning. This thesis serves to characterize and consolidate the now well-established program of stellar occultation observations at the SAAO.

Zafiirah Hosenie, *MSc, NWU*

Title: Source classification in deep radio surveys using machine learning techniques
Supervisors: Dr. Nadeem Oozeer (SARAO), Prof. Bruce Bassett (AIMS/UCT/SAAO), Prof. Ilani Loubser (NWU)

Abstract:
Until now radio galaxies have primarily been classified using the human neural system. The Square Kilometre Array (SKA) will, however, produce a very large amount of science data, extending into the multiple-petabyte range. Therefore there is an urgent need to develop new, automated techniques to maximally exploit the SKA data. Machine Learning (ML) techniques are currently being used in several fields of Astrophysics and in this thesis we comprehensively explore ML as a way to distinguish point and extended sources (P-E) and to classify radio galaxies as belonging to Fanaroff-Riley class I or II (FRI-FRII).

Our first step was to classify radio sources based on their morphology using filtering methods. We used images from the Sydney University Molonglo Sky Survey (SUMSS) and compared the following techniques: (i) the LULU operators and the Discrete Pulse Transform (DPT) algorithms with a low and high pass filtering. The LULU and DPT algorithms have only been successful in classifying extended sources and are computationally expensive. (ii) we then explored other techniques to extract the sources by applying a high pass filter to the radio images. Using Otsu thresholding and Gaussian filtering methods, we have been able to extract not only extended sources but also made gains in computational time. Our next approach has been to classify P-E and FRI-FRII sources using various ML algorithms. These included the Multi Layer Perceptron (MLP), Random Forest (RF), k-Nearest Neighbours (kNN) and Naive Bayes (NB) which require specific features of the radio images as inputs. We implemented shapelet analysis to decompose the radio images into their corresponding shapelet coefficients which are then fed into the ML algorithms. For P-E discrimination, a neural network was the most effective algorithm, with an accuracy of 89% and area under curve (AUC) value of 93%. For FRI-FRII sources, the RF algorithm proved to be the best with an accuracy of 75% and AUC value of 74%.

The final stage of this thesis has been to apply deep learning to FRI-FRII source classification in the form of a Convolutional Neural Network (CNN). For the first time in radio astronomy we have added a Generative Adversarial Neural (GAN) network to generate realistic looking data to supplement the real data during training. The result from the CNN+GAN algorithm has proved to be better than both the RF algorithm and the CNN alone with standard data augmentation (flipping and rotation), yielding an accuracy of 84% and AUC value of 85%, showing that combining GANs with convolutional networks for radio astronomy is likely to add significant value in the era of the SKA.

For the first time in radio astronomy we have added a Generative Adversarial Neural (GAN) network to generate realistic looking data to supplement the real data during training.

Nicole Thomas, *MSc, UWC*

Title: Galaxy clustering as a probe for galaxy evolution in simulations
Supervisor: Prof. Romeel Davé (SAAO/UWC) and Prof. Roy Maartens (UWC)

Abstract:
Studying clustering on small scales (<10Mpc) over a large span of redshifts allows us to connect galaxies to underlying cosmic large-scale structure, and thereby provide constraints on the physical processes that drive galaxy evolution. Relatedly, studying the relative bias of galaxies and their halo occupancy quantifies how the underlying dark matter distribution is traced by baryons in galaxies. Comparing model predictions to current and future multi-wavelength galaxy surveys, enables a greater understanding of how galaxy formation processes impact the relationship between galaxies and dark matter.

In this thesis I study the clustering and bias of galaxies in cosmological galaxy formation simulations. To conduct this study, I use MUFASA – a state-of-the-art suite of cosmological hydrodynamical simulations (Davé et al. 2016). The number of galaxies within a probed parameter bin decreases with increasing redshift. I thus examine clustering and bias over a redshift range from z=0–2.5 and z=0–3 using MUFASA's fiducial $(50\text{Mpc/h})^3$ volume, which has 512^3 dark matter particles and 512^3 gas elements.

I find that for the full sample of galaxies in the MUFASA simulations, the amplitude of clustering decreases with redshift until z=2, after which the amplitude increases with redshift. The dark matter clustering amplitude decreases with redshift, and thus with this we see an increase in bias, which is the ratio of clustering strength of baryons to that of the dark matter distribution, with increasing redshift. At a given redshift, we see an increase in clustering amplitude with stellar mass, M_*, as well as with increasing brightness in r-band luminosity, M_r. However, we see a decrease in clustering amplitude with specific star formation rate, sSFR, as well as brightness in the Near-UV luminosities, M_{NUV}. We observe no clustering dependence on HI mass, M_{HI}, at a given redshift.

As a function of redshift, we observe a decrease in clustering amplitude for a given M_* bin. We do not see any obvious trend with M_r bin, however for sSFR, M_{NUV}, and M_{HI} bins we see an increase in clustering amplitude as a function of redshift. There is a general increase in bias as at a given redshift across all mentioned parameters. There seems to be no bias evolution with M_* bin however, but for all other parameters, we see a general increasing trend with redshift.

These results suggest that galaxies that are more red, quiescent, and gas-poor cluster more strongly than blue, star-forming, gas-rich galaxies. Since higher-mass dark matter halos cluster more strongly, this indicates that these halos are more likely to host groups of passive, gas-poor galaxies. Since the detailed manner in which passive and star-forming galaxies populate dark matter halos depends on detailed galaxy formation processes such as feedback from star formation and black holes, future comparisons to upcoming surveys such as MIGHTEE and VIDEO will provide an important path towards constraining these uncertain feedback processes.

Student profiles

SAAO takes pride in the rich diversity and culture of our students who come from all over the world and, in particular, from other African countries such as Rwanda, Uganda, Ethiopia, Mauritius, Sudan, Burkina Faso, Lebanon, Madagascar, and more.

During 2018, 13 SAAO staff members supervised or co-supervised 9 MSc and 20 PhD students registered at various South African universities (the majority at UCT).

Eleven students spent at least 50% of their time at SAAO, while others were based at AIMS, UCT or UWC. Most of them are studying astronomy, although there are also students from engineering and computer science.

Three MSc and five PhD students graduated during the year. SAAO also appoints a number of honours students and interns every year across all departments, particularly unemployed graduates.

During 2018, 13 SAAO staff members supervised or co-supervised 9 MSc and 20 PhD students.

PhD students

Etsegenet Alemu, *UCT*

Luminous Infrared Variables in Nearby Galaxies
Supervisor: Patricia Whitelock (SAAO/UCT)

Gerald Nathan Balekaki, *UCT*

A scalable database model for radio frequency interference data: A case of the MeerKAT telescope
Supervisors: Michelle Kuttel (UCT), Anja Schröder (SAAO), Sarah Blyth (UCT)

Jamie Bok, *UCT*

An HI study of isolated and pair galaxies: the MIR SFR–M* sequence
Supervisors: Rosalind Skelton (SAAO), Tom Jarrett (UCT)

Hannes Breytenbach, *UCT*

Magnetic cataclysmic variables
Supervisors: David Buckley (SAAO), Patrick Woudt (UCT)

Emmanuel Dufourq, *UCT*

Evolutionary deep learning
Supervisor: Bruce Bassett (AIMS/UCT/SAAO)

Michael Hlabathe, *UCT*

Reverberation mapping of active galactic nuclei
Supervisors: Encarni Romero Colmenero (SAAO), Patricia Whitelock (SAAO/UCT)

Zwidofhelangani Khangale, *UCT*

Accretion processes in magnetic cataclysmic variables
Supervisors: Stephen Potter (SAAO), Patrick Woudt (UCT)

Blaine Lomberg, *UCT*

Developing instrumentation for use in studies of exo-ring systems
Supervisors: Rudi Kuhn (SAAO), Patricia Whitelock (SAAO/UCT)

Antoine Mahoro, *UCT*

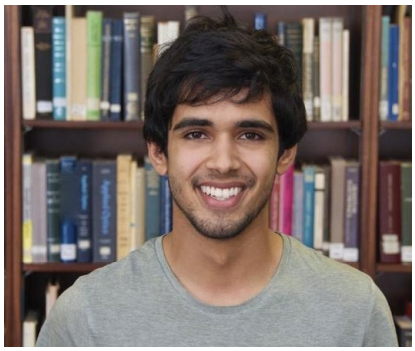
Outflows from star-forming galaxies and AGN
Supervisors: Petri Väisänen (SAAO), Kurt van der Heyden (UCT)

Mokhine Motsoaledi, *UCT*

Accretion processes in cataclysmic variables: Insights from optical transient surveys
Supervisors: Patrick Woudt (UCT), David Buckley (SAAO)

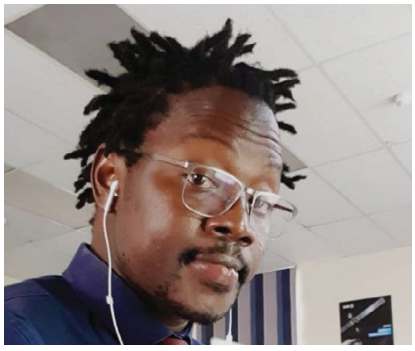
Bynish Paul, *UJ*

Investigating optical Fe II emission in the active galactic nuclei of narrow line Seyfert1 galaxies
Supervisors: Hartmut Winkler (UJ), Stephen Potter (SAAO)



Ethan Roberts, *UCT*

Frontiers in machine learning and Bayesian statistics in science
Supervisor: Bruce Bassett (AIMS/UCT/SAAO)



Blaise Tapsoba, *UCT*

Study of star-formation, kinematics, gas outflows and stellar populations in nearby star-forming early type galaxies with nuclear rings/spirals
Supervisors: Petri Väisänen (SAAO), Tom Jarrett (UCT)

Nicole Thomas, *UWC*

Probing galaxy evolution in simulations and multi-wavelength surveys
Supervisors: Romeel Davé (SAAO/UWC), Ed Elson (UWC)

Naomi van Jaarsveld, *UCT*

Multi-wavelength study of neutron stars in the Magellanic Clouds
Supervisor: Vanessa McBride (SAAO/OAD/UCT), David Buckley (SAAO)

MSc students

Curtly Blows. *UCT*

Reinforcement learning for telescope optimisation
Supervisor: Bruce Bassett (AIMS/UCT/SAAO)

Nazir Makda. *UCT*

Ultra-diffuse galaxies in Stripe 82 clusters
Supervisors: Rosalind Skelton (SAAO), Sarah Blyth (UCT)

Orapeleng Mogawana. *UCT*

Simulating massive exploding stars and making model predictions of their radio emission
Supervisor: Shazrene Mohamed (SAAO/UCT)

Kimeel Sooknunan. *UCT*

Classification of multiwavelength transients with machine learning
Supervisors: Michelle Lochner (UCT), Bruce Bassett (AIMS/UCT/SAAO)

Melaku Sisay Tafere. *UCT*

Gas flows and feedback in star-forming galaxies
Supervisors: Petri Väisänen (SAAO), Kurt van der Heyden (UCT)

Abubakr Yagob. *UCT*

Dispersion measure (DM) variations in pulsar observations
Supervisors: Shazrene Mohamed (SAAO/UCT), Maciej Serylak (SARAO)

Honours students

Gregory Austin (UCT), supervised by Anja Schröder (SAAO) and Geoff Nitschke (UCT)

Jordan Barkai (UCT), supervised by Shazrene Mohammed (SAAO)

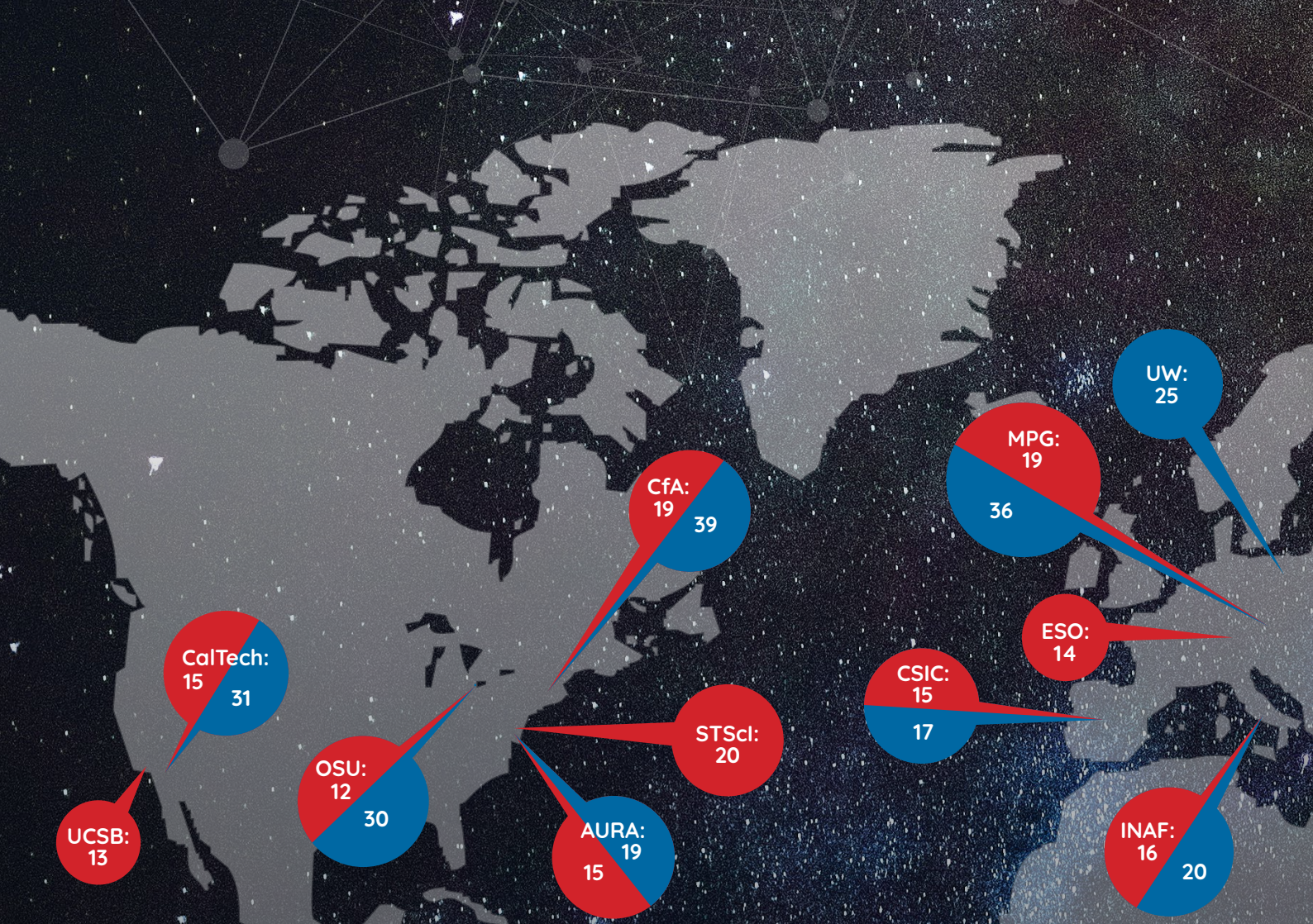
Kelebogile Bonokwane (UCT), supervised by Brent Miszalski (SAAO)

Dante Michael Hewitt (UCT), supervised by Retha Pretorius (SAAO)

David Griffin Jones (UCT), supervised by Anja Schröder (SAAO) and Geoff Nitschke (UCT)

Shilpa Ranchod (UCT), supervised by Rosalind Skelton (SAAO)

SAAO PERFORMANCE



Publications

117 REFEREED PUBLICATIONS BY SAAO STAFF — 66 of which use SAAO & hosted facilities

114 REFEREED PUBLICATIONS BY NON-SAAO STAFF — using SAAO & hosted facilities

231 TOTAL REFEREED PUBLICATIONS

Breakdown of refereed publications using SAAO & hosted facilities:

SALT	60
1.9-m	16
1.0-m	9
0.75-m	5
IRSF	20
MeerLICHT	2
BiSON	7
Kelt-S	9
KMTNet	23
MONET	1
LCOGT	16
Solaris	1
MASTER	10
SuperWASP (de-commissioned)	15
ASAS-SN	1
0.5-m (de-commissioned)	5

SAAO has a number of publications each year, many of which are collaborations of SAAO researchers with scientists from some of the most prestigious institutions across the globe. The impact of these publications stems not only from their contributions to the field of astronomy, but are highlighted in the number of citations and the headlines that these contributions sparked across the globe.

Top 12 Collaborations:

Organisations SAAO has most frequently collaborated with, based on 117 publications

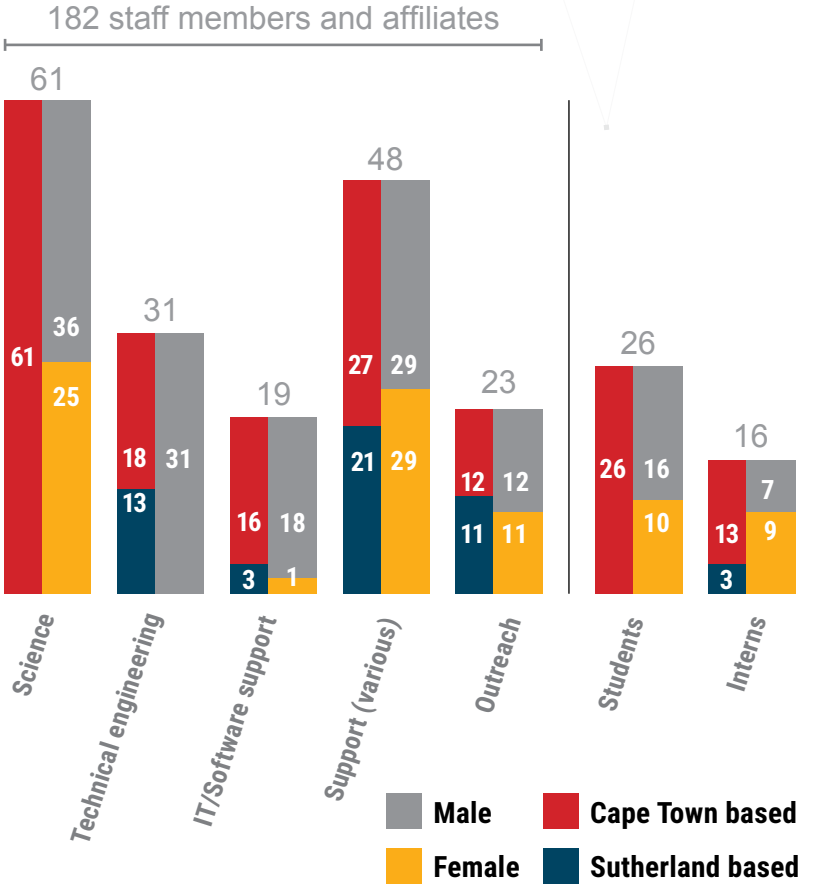
UCT (University of Cape Town), South Africa	22
STScI (Space Telescope Science Institute), USA	20
CfA (Center for Astrophysics), USA	19
MPG (Max Planck Society), Germany	19
INAF (National Institute for Astrophysics), Italy	16
AURA (Association of Universities for Research in Astronomy), USA	15
CSIC (Spanish Research Council), Spain	15
CalTech (California Institute of Technology), USA	15
ESO (European Southern Observatory), Europe	14
UCSB (University of California, Santa Barbara), USA	13
OSU (Ohio State University), USA	12
UWC (University of the Western Cape), South Africa	11

Organisations that have published on SAAO & hosted facilities, based on 180 publications

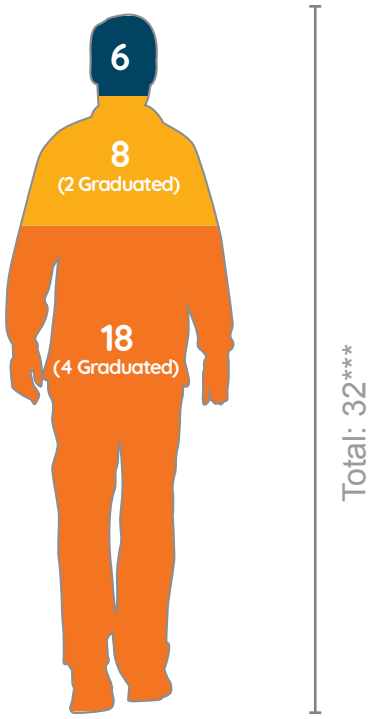
SAAO (South African Astronomical Observatory), South Africa	66
CfA (Center for Astrophysics), USA	39
MPG (Max Planck Society), Germany	36
CalTech (California Institute of Technology), USA	31
OSU (State University), USA	30
KASI (Korea Astronomy & Space Science), Korea	28
UW (University of Warsaw), Poland	25
CBNU (Chungbuk National University), Korea	20
INAF (National Institute for Astrophysics), Italy	20
UC (University of Canterbury), New Zealand	20
AURA (Association of Universities for Research in Astronomy), USA	19
CSIC (Spanish Research Council), Spain	17

Staff*

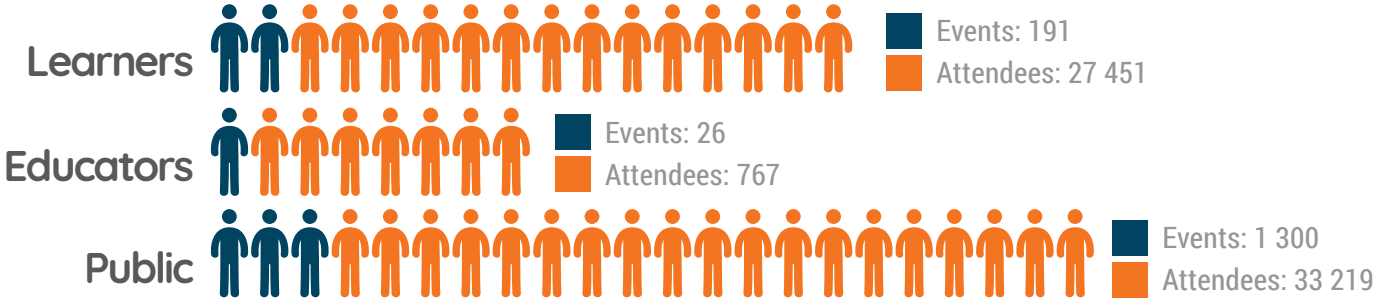
By Department



Students** supervised by SAAO staff:



Outreach*



* *Based on the reporting period Apr 2018 - Mar 2019*
** *Based on the reporting period Jan 2018 - Dec 2018*
*** *The numbers differ slightly from page 76 due to administrative reasons*

APPENDIX

Publication lists*

Refereed Publications**

Publications with SAAO affiliation

Agarwal, S., Davé, R., & Bassett, B. A.: "Painting galaxies into dark matter haloes using machine learning", 2018, MNRAS, 478, 3410

Alonso-Santiago, J., Marco, A., Negueruela, I., et al.: "NGC 3105: a young open cluster with low metallicity", 2018, A&A 616, A124

Amvrosiadis, A., Eales, S. A., Negrello, M., et al.: "ALMA observations of lensed Herschel sources: testing the dark matter halo paradigm", 2018, MNRAS, 475, 4939

Ansdell, M., Oelkers, R. J., Rodriguez, J. E., et al.: "Identification of young stellar variables with KELT for K2 - II. The Upper Scorpius association", 2018, MNRAS, 473, 1231

Arkhipova, V. P., Parthasarathy, M., Ikonnikova, N. P., et al.: "Line identification and photometric history of the hot post-AGB star Hen 3-1013 (IRAS 14331-6435)", 2018, MNRAS, 481, 3935

Astropy Collaboration, Price-Whelan, A. M., Sipőcz, B. M., Günther, et al.: "The Astropy Project: Building an Open-science Project and Status of the v2.0 Core Package", 2018, AJ, 156, 123

Aydi, E., Orio, M., Beardmore, A. P., et al.: "Multiwavelength observations of V407 Lupi (ASASSN-16kt) - a very fast nova erupting in an intermediate polar", 2018, MNRAS, 480, 572

Aydi, E., Page, K. L., Kuin, N. P. M., et al.: "Multiwavelength observations of nova SMCN 2016-10a - one of the brightest novae ever observed", 2018, MNRAS, 474, 2679

Baglio, M. C., Russell, D. M., Casella, P., et al.: "A Wildly Flickering Jet in the Black Hole X-Ray Binary MAXI J1535-571", 2018, ApJ, 867, 114

Balona, L. A.: "Equally spaced periods in the δ Scuti star KIC 5123889", 2018, MNRAS, 475, 359

Balona, L. A.: "The effect of tides on self-driven stellar pulsations", 2018, MNRAS, 476, 4840

Balona, L. A.: "Gaia luminosities of pulsating A-F stars in the Kepler field", 2018, MNRAS, 479, 183

Balona, L. A.: "Pulsation in Intermediate-Mass Stars", 2018, Frontiers in Astronomy and Space Sciences, 5, 43

Bennett, D. P., Udalski, A., Han, C., et al.: "The First Planetary Microlensing Event with Two Microlensed Source Stars", 2018, AJ, 155, 141

Boffin, H. M. J., Jones, D., Wesson, R., et al.: "When nature tries to trick us. An eclipsing eccentric close binary superposed on the central star of the planetary nebula M 3-2", 2018, A&A, 619, A84

Bond, H. E., & Miszalski, B.: "Spectroscopy of V341 Arae: A Nearby Nova-like Variable Inside a Bow Shock Nebula", 2018, PASP, 130, 094201

Booth, J. A., & Crause, L. A.: "How to talk so your engineer will listen, how to listen so your scientist will talk: the human side of astronomical instrument development", 2018, Proc. SPIE, 10705, 1070509

Booth, J. A., Shara, M., Crawford, S. M., & Crause, L. A.: "Mini-tracker concepts for the SALT transient follow-up program", 2018, Proc. SPIE, 10700, 107000S

Briceño, C., Heathcote, S., Cecil, G., et al.: "The SOAR telescope atmospheric dispersion corrector", 2018, Proc. SPIE, 10700, 107003Z

Brink, J. D., Strydom, O. J., Hulme, S. N., et al.: "Performance of the updated Southern African Large Telescope prime-focus guidance system", 2018, Proc. SPIE, 10706, 1070668

Brink, J. D., Strydom, O. J., Pretorius, M. L., & Vaisanen, P. S. M.: "A high-efficiency low-resolution spectrograph design for SALT", 2018, Proc. SPIE, 10706, 107066H

Browne, K. R. J., & Hettlage, C.: "More effective fault management at SALT", 2018, Proc. SPIE, 10704, 1070423

Buckley, D., Potter, S., Meintjes, P., Marsh, T., & Gänsicke, B.: "Polarimetric Evidence of the First White Dwarf Pulsar: The Binary System AR Scorpii", 2018, Galaxies, 6, 14

Buckley, D. A. H., Andreoni, I., Barway, S., et al.: "A comparison between SALT/SAAO observations and kilonova models for AT 2017gfo: the first electromagnetic counterpart of a gravitational wave transient - GW170817", 2018, MNRAS, 474, L71

** Based on the reporting period Jan 2018 - Dec 2018*
*** Publications in peer-reviewed, ISI approved journals*

Coetzee, J.C., Shara, M., Williams, T.B., et al. 2018, Proc SPIE, 107040P

Collins, K. A., Collins, K. I., Pepper, J., et al.: "The KELT Follow-up Network and Transit False-positive Catalog: Pre-vetted False Positives for TESS", 2018, AJ, 156, 234

Colón, K. D., Zhou, G., Shporer, A., et al.: "A Large Ground-based Observing Campaign of the Disintegrating Planet K2-22b", 2018, AJ, 156, 227

Cracco, V., Orio, M., Ciroi, S., et al.: "Supersoft X-Ray Sources Identified with Be Binaries in the Magellanic Clouds", 2018, ApJ, 862, 167

Crause, L. A., Butler, R. P., Nave, G., et al.: "Commissioning the SALT High Resolution Spectrograph's iodine cell", 2018, Proc. SPIE, 10702, 107025S

Cui, W., Knebe, A., Yepes, G., et al.: "The Three Hundred project: a large catalogue of theoretically modelled galaxy clusters for cosmological and astrophysical applications", 2018, MNRAS, 480, 2898

De Rosa, G., Fausnaugh, M. M., Grier, C. J., et al.: "Velocity-resolved Reverberation Mapping of Five Bright Seyfert 1 Galaxies", 2018, ApJ, 866, 133

Drinkwater, M. J., Byrne, Z. J., Blake, C., et al.: "The WiggleZ Dark Energy Survey: final data release and the metallicity of UV-luminous galaxies", 2018, MNRAS, 474, 4151

Erasmus, N., McNeill, A., Mommert, M., et al.: "Taxonomy and Light-curve Data of 1000 Serendipitously Observed Main-belt Asteroids", 2018, ApJSS, 237, 19

Eyres, S. P. S., Evans, A., Zijlstra, A., et al.: "ALMA reveals the aftermath of a white dwarf-brown dwarf merger in CK Vulpeculae", 2018, MNRAS, 481, 4931

Fausnaugh, M. M., Starkey, D. A., Horne, K., et al.: "Continuum Reverberation Mapping of the Accretion Disks in Two Seyfert 1 Galaxies", 2018, ApJ, 854, 107

Figueira, J., José, J., García-Berro, E., et al.: "Three-dimensional simulations of the interaction between the nova ejecta, accretion disk, and companion star", 2018, A&A, 613, A8

Finlator, K., Keating, L., Oppenheimer, B. D., Davé, R., & Zackrisson, E.: "Reionization in Technicolor", 2018, MNRAS, 480, 2628

Gilbank, D. G., Barrientos, L. F., Ellingson, E., et al.: "Spectroscopic characterization of galaxy clusters in RCS-1: spectroscopic confirmation, redshift accuracy, and dynamical mass-richness relation", 2018, MNRAS, 476, 1991

Giles, H. A. C., Bayliss, D., Espinoza, N., et al.: "K2-140b - an eccentric 6.57 d transiting hot Jupiter in Virgo", 2018, MNRAS, 475, 1809

Goldman, S. R., van Loon, J. T., Gómez, J. F., et al.: "A dearth of OH/IR stars in the Small Magellanic Cloud", 2018, MNRAS, 473, 3835

Gvaramadze, V. V., Kniazev, A. Y., Maryeva, O. V., & Berdnikov, L. N.: "Optical spectroscopy of the blue supergiant Sk-69° 279 and its circumstellar shell with SALT", 2018, MNRAS, 474, 1412

Gvaramadze, V. V., Alexashov, D. B., Katushkina, O. A., & Kniazev, A. Y.: "Modelling interstellar structures around Vela X-1", 2018, MNRAS, 474, 4421

Halpern, J. P., Thorstensen, J. R., Cho, P., et al.: "Optical Studies of 15 Hard X-Ray Selected Cataclysmic Binaries", 2018, AJ, 155, 247

Hassan, S., Davé, R., Mitra, S., et al.: "Constraining the contribution of active galactic nuclei to reionization", 2018, MNRAS, 473, 227

Hernández Santisteban, J. V., Knigge, C., Pretorius, M. L., Sullivan, M., & Warner, B.: "The space density of post-period minimum Cataclysmic Variables", 2018, MNRAS, 473, 3241

Hettlage, C., Romero Colmenero, E., Crawford, S., et al.: "Preparing SALT's software for the future", 2018, Proc. SPIE, 10704, 107042D

Holdsworth, D. L., Kurtz, D. W., Saio, H., et al.: "Whole Earth Telescope discovery of a strongly distorted quadrupole pulsation in the largest amplitude rapidly oscillating Ap star", 2018, MNRAS, 473, 91

Holdsworth, D. L., Saio, H., Bowman, D. M., et al.: "Suppressed phase variations in a high amplitude rapidly oscillating Ap star pulsating in a distorted quadrupole mode", 2018, MNRAS, 476, 601

Holdsworth, D. L., Saio, H., Sefako, R. R., & Bowman, D. M.: "LCO observations of a super-critical distorted pulsation in the roAp star J0855 (TYC 2488-1241-1)", 2018, MNRAS, 480, 2405

Holler, B. J., Milam, S. N., Bauer, J. M., et al.: "Solar system science with the Wide-Field Infrared Survey Telescope", 2018, Journal of Astronomical Telescopes, Instruments, and Systems, 4, 034003

Huang, C. D., Riess, A. G., Hoffmann, S. L., et al.: "A Near-infrared Period-Luminosity Relation for Miras in NGC 4258, an Anchor for a New Distance Ladder", 2018, ApJ, 857, 67

Hulme, S. N., Maartens, D. S., Brink, J. D., & Koeslag, A. R.: "Development of a centralised change logging system for the Southern African Large Telescope", 2018, Proc. SPIE, 10707, 107072N

Hundertmark, M., Street, R. A., Tsapras, Y., et al.: "RoboTAP: Target priorities for robotic microlensing observations", 2018, A&A, 609, A55

Ita, Y., Matsunaga, N., Tanabé, T., et al.: "A near-infrared variable star survey in the Magellanic Clouds: the Small Magellanic Cloud data", 2018, MNRAS, 481, 4206

Ikiewicz, K., Mikołajewska, J., Miszalski, B., Kozłowski, S., & Udalski, A.: "A D'-type symbiotic binary in the planetary nebula SMP LMC 88", 2018, MNRAS, 476, 2605

Johnson, M. C., Rodriguez, J. E., Zhou, G., et al.: "KELT-21b: A Hot Jupiter Transiting the Rapidly Rotating Metal-poor Late-A Primary of a Likely Hierarchical Triple System", 2018, AJ, 155, 100

Joyce, M., & Chaboyer, B.: "Not All Stars Are the Sun: Empirical Calibration of the Mixing Length for Metal-poor Stars Using One-dimensional Stellar Evolution Models", 2018, ApJ, 856, 10

Joyce, M., & Chaboyer, B.: "Classically and Asteroseismically Constrained 1D Stellar Evolution Models of α Centauri A and B Using Empirical Mixing Length Calibrations", 2018, ApJ, 864, 99

Karim, M. T., Fox, A. J., Jenkins, E. B., et al.: "Probing the Southern Fermi Bubble in Ultraviolet Absorption Using Distant AGNs", 2018, ApJ, 860, 98

Knebe, A., Pearce, F. R., Gonzalez-Perez, V., et al.: "Cosmic CARNage I: on the calibration of galaxy formation models", 2018, MNRAS, 475, 2936

Kniazev, A. Y., Egorova, E. S., & Pustilnik, S. A.: "Study of galaxies in the Eridanus void. Sample and oxygen abundances", 2018, MNRAS, 479, 3842

Koeslag, A. R., Brink, J. D., Hulme, S. N., Strydom, O. J., & Maartens, D. S.: "Image processing for a pyramid wavefront sensor equipped guide probe on SALT", 2018, Proc. SPIE, 10707, 107072M

Kool, E. C., Ryder, S., Kankare, E., et al.: "First results from GeMS/GSAOI for project SUNBIRD: Supernovae UNmasked By Infra-Red Detection", 2018, MNRAS, 473, 5641

Kraan-Korteweg, R. C., van Driel, W., Schröder, A. C., Ramatsoku, M., & Henning, P. A.: "The Nançay H I Zone of Avoidance survey of 2MASS bright galaxies", 2018, MNRAS, 481, 1262

Labadie-Bartz, J., Chojnowski, S. D., Whelan, D. G., et al.: "Outbursts and Disk Variability in Be Stars", 2018, AJ, 155, 53

Lemasle, B., Hajdu, G., Kovtyukh, V., et al.: "Milky Way metallicity gradient from Gaia DR2 F/1O double-mode Cepheids", 2018, A&A, 618, A160

Letarte, B., Hill, V., Tolstoy, E., et al.: "A high-resolution VLT/FLAMES study of individual stars in the centre of the Fornax dwarf spheroidal galaxy (Corrigendum)", 2018, A&A, 613, C1

Li, Q., Narayanan, D., Davè, R., & Krumholz, M. R.: "Dark Molecular Gas in Simulations of z˜ 0 Disk Galaxies", 2018, ApJ, 869, 73

Love, J., Coetzee, J. C., Gajjar, H., & Wilkinson, M.: "Deskilling SALT primary mirror recoating process", 2018, Proc. SPIE, 10704, 1070425

Maartens, D. S., & Brink, J. D.: "Selecting a simple, natively implemented middleware solution for the SALT control system", 2018, Proc. SPIE, 10707, 107070E

Malkov, O., Karpov, S., Kilpio, E., et al.: "Interstellar extinction from photometric surveys: application to four high-latitude areas", 2018, Open Astronomy, 27, 62

Malkov, O., Karpov, S., Kovaleva, D., et al.: "Verification of Photometric Parallaxes with Gaia DR2 Data", 2018, Galaxies, 7, 7

Maseda, M. V., van der Wel, A., Rix, H.-W., et al.: "The Number Density Evolution of Extreme Emission Line Galaxies in 3D-HST: Results from a Novel Automated Line Search Technique for Slitless Spectroscopy", 2018, ApJ, 854, 29

Mattila, K., Haas, M., Haikala, L. K., et al.: "Optical and UV surface brightness of translucent dark nebulae. Dust albedo, radiation field, and fluorescence emission by H_2", 2018, A&A, 617, A42

Mattila, S., Pérez-Torres, M., Efstathiou, A., et al.: "A dust-enshrouded tidal disruption event with a resolved radio jet in a galaxy merger", 2018, Science, 361, 482

McBride, V., Venugopal, R., Hoosain, M., Chingozha, T., & Govender, K.: "The potential of astronomy for socioeconomic development in Africa", 2018, Nature Astronomy, 2, 511

Mentel, R. T., Kenworthy, M. A., Cameron, D. A., et al.: "Constraining the period of the ringed secondary companion to the young star J1407 with photographic plates", 2018, A&A, 619, A157

Miszalski, B., Manick, R., Mikołajewska, J., et al.: "SALT HRS discovery of a long-period double-degenerate binary in the planetary nebula NGC 1360", 2018, MNRAS, 473, 2275 [Erratum: MNRAS 474, 646]

Miszalski, B., Manick, R., Mikołajewska, J., Van Winckel, H., & Ilkiewicz, K.: "SALT HRS Discovery of the Binary Nucleus of the Etched Hourglass Nebula MyCn 18", 2018, PASA, 35, e027

Mitchell, C. J., Sellwood, J. A., Williams, T. B., et al.: "The RINGS Survey. III. Medium-resolution Hα Fabry-Pérot Kinematic Data Set", 2018, AJ, 155, 123

Narayanan, D., Conroy, C., Davé, R., Johnson, B. D., & Popping, G.: "A Theory for the Variation of Dust Attenuation Laws in Galaxies", 2018, ApJ, 869, 70

Nesvold, E. R., Greenberg, A., Erasmus, N., et al.: "The Deflector Selector: A machine learning framework for prioritizing hazardous object deflection technology development", 2018, Acta Astronautica, 146, 33

Oelkers, R. J., Rodriguez, J. E., Stassun, K. G., et al.: "Variability Properties of Four Million Sources in the TESS Input Catalog Observed with the Kilodegree Extremely Little Telescope Survey", 2018, AJ, 155, 39

Orio, M., Ness, J.-U., Dobrotka, A., et al.: "What We Learn from the X-Ray Grating Spectra of Nova SMC 2016", 2018, ApJ, 862, 164

Pancoast, A., Barth, A. J., Horne, K., et al.: "Stability of the Broad-line Region Geometry and Dynamics in Arp 151 Over Seven Years", 2018, ApJ, 856, 108

Potter, S. B., & Buckley, D. A. H.: "Discovery of spin-modulated circular polarization from IGR J17014-4306, the remnant of Nova Scorpii 1437 AD", 2018, MNRAS, 473, 4692

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Potter, S. B., & Buckley, D. A. H.: "Time series photopolarimetry and modelling of the white dwarf pulsar in AR Scorpii", 2018, MNRAS, 481, 2384

Pović, M., Backes, M., Baki, P., et al.: "Development in astronomy and space science in Africa", 2018, Nature Astronomy, 2, 507

Privon, G. C., Narayanan, D., & Davé, R.: "On the Interpretation of Far-infrared Spectral Energy Distributions. I. The 850 μm Molecular Mass Estimator", 2018, ApJ, 867, 102

Proxauf, B., da Silva, R., Kovtyukh, V. V., et al.: "A new and homogeneous metallicity scale for Galactic classical Cepheids. I. Physical parameters", 2018, A&A, 616, A82

Rafieferantsoa, M., & Davé, R.: "MUFASA: the strength and evolution of galaxy conformity in various tracers", 2018, MNRAS, 475, 955

Rafieferantsoa, M., Andrianomena, S., & Davé, R.: "Predicting the neutral hydrogen content of galaxies from optical data using machine learning", 2018, MNRAS, 479, 4509

Ramiaramanantsoa, T., Moffat, A. F. J., Harmon, R., et al.: "BRITE-Constellation high-precision time-dependent photometry of the early O-type supergiant ζ Puppis unveils the photospheric drivers of its small- and large-scale wind structures", 2018, MNRAS, 473, 5532

Ramstedt, S., Mohamed, S., Olander, T., et al.: "CO envelope of the symbiotic star R Aquarii seen by ALMA", 2018, A&A, 616, A61

Romeo, A. B., & Mogotsi, K. M.: "Angular momentum and local gravitational instability in galaxy discs: does Q correlate with j or M ?", 2018, MNRAS, 480, L23

Romero-Colmenero, E., Väisänen, P., Williams, T., et al.: "Astronomy operations with the Southern African Large Telescope (SALT): SALT is doing great!", 2018, Proc. SPIE, 10704, 107040O

Sako, M., Bassett, B., Becker, A. C., et al.: "The Data Release of the Sloan Digital Sky Survey-II Supernova Survey", 2018, PASP, 130, 064002

Shen, K. J., Boubert, D., Gänsicke, B. T., et al.: "Three Hypervelocity White Dwarfs in Gaia DR2: Evidence for Dynamically Driven Double-degenerate Double-detonation Type Ia Supernovae", 2018, ApJ, 865, 15

Shipley, H. V., Lange-Vagle, D., Marchesini, D., et al.: "HFF-DeepSpace Photometric Catalogs of the 12 Hubble Frontier Fields, Clusters, and Parallels: Photometry, Photometric Redshifts, and Stellar Masses", 2018, ApJSS, 235, 14

Sil'chenko, O. K., Kniazev, A. Y., & Chudakova, E. M.: "The Structure of Large-scale Stellar Disks in Cluster Lenticular Galaxies", 2018, AJ, 156, 118

Silva, A., Marchesini, D., Silverman, J. D., et al.: "Galaxy Mergers up to Z < 2.5. I. The Star Formation Properties of Merging Galaxies at Separations of 3-15 kpc", 2018, ApJ, 868, 46

Simon, E. L., Coetzee, J. C., Browne, K. R. J., Wiid, E. P., & Williams, T.: "SALT integrated safety management system", 2018, Proc. SPIE, 10704, 1070424

Siverd, R. J., Collins, K. A., Zhou, G., et al.: "KELT-19Ab: A P ˜ 4.6-day Hot Jupiter Transiting a Likely Am Star with a Distant Stellar Companion", 2018, AJ, 155, 35

Stanishev, V., Goobar, A., Amanullah, R., et al.: "Type Ia supernova Hubble diagram with near-infrared and optical observations", 2018, A&A, 615, A45

Swanevelder, P., Carter, D., O'Connor, J., et al.: "Design and results for the SAAO wide-field nasmyth camera", 2018, Proc. SPIE, 10702, 107022K

Tominaga, N., Tanaka, M., Morokuma, T., et al.: "Subaru Hyper Suprime-Cam Survey for an optical counterpart of GW170817", 2018, PASJ, 70, 28

Udalski, A., Han, C., Bozza, V., et al.: "OGLE-2014-BLG-0289: Precise Characterization of a Quintuple-peak Gravitational Microlensing Event", 2018, ApJ, 853, 70

Vafaei Sadr, A., Farhang, M., Movahed, S. M. S., Bassett, B., & Kunz, M.: "Cosmic string detection with tree-based machine learning", 2018, MNRAS, 478, 1132

Vaghmare, K., Barway, S., Väisänen, P., et al.: "A SALT spectral study of S0s hosting pseudobulges", 2018, MNRAS, 480, 4931

van Jaarsveld, N., Buckley, D. A. H., McBride, V. A., et al.: "Identification of high-mass X-ray binaries selected from XMM-Newton observations of the LMC$_\star$", 2018, MNRAS, 475, 3253

van Rooyen, R., Maartens, D. S., & Martinez, P.: "Autonomous observation scheduling in astronomy", 2018, Proc. SPIE, 10704, 1070410

Väisänen, P., Crause, L., Gilbank, D., et al.: "SALT and SAAO strategy, focusing on the time-domain: process, plans, and challenges", 2018, Proc. SPIE, 10704, 107040A

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Whitelock, P. A.: "AGB Variables in Local Group Dwarf Irregular Galaxies", 2018, Stellar Populations and the Distance Scale, 514, 49

Wiid, E. P., Browne, K., Love, J. J., et al.: "Observing in higher humidity", 2018, Proc. SPIE, 10704, 1070429

Xu, S., Rappaport, S., van Lieshout, R., et al.: "A dearth of small particles in the transiting material around the white dwarf WD 1145+017", 2018, MNRAS, 474, 4795

Publications of non-SAAO researchers and based on data obtained with SAAO or SAAO-hosted facilities

Albrow, M. D., Yee, J. C., Udalski, A., et al.: "OGLE-2016-BLG-1266: A Probable Brown Dwarf/Planet Binary at the Deuterium Fusion Limit", 2018, ApJ, 858, 107

Aller, A., Lillo-Box, J., Vučković, M., et al.: "A new look inside planetary nebula LoTr 5: a long-period binary with hints of a possible third component", 2018, MNRAS, 476, 1140

Baroch, D., Morales, J. C., Ribas, I., et al.: "The CARMENES search for exoplanets around M dwarfs. Nine new double-line spectroscopic binary stars", 2018, A&A, 619, A32

Basu, S., & Kinnane, A.: "The Robustness of Asteroseismic Estimates of Global Stellar Parameters to Surface Term Corrections", 2018, ApJ, 869, 8

Binks, A. S., Jeffries, R. D., & Ward, J. L.: "Searching for new young stars in the Northern hemisphere: the Pisces moving group", 2018, MNRAS, 473, 2465

Boersma, C., Bregman, J., & Allamandola, L. J.: "The Charge State of Polycyclic Aromatic Hydrocarbons across a Reflection Nebula, an H II Region, and a Planetary Nebula", 2018, ApJ, 858, 67

Braga, V. F., Bhardwaj, A., Contreras Ramos, R., et al.: "Structure and kinematics of Type II Cepheids in the Galactic bulge based on near-infrared VVV data", 2018, A&A, 619, A51

Brown, S., Moon, D.-S., Ni, Y. Q., et al.: "High-cadence Multi-color Observations of the Dwarf Nova KSP-OT-201503a by the KMTNet Supernova Program", 2018, ApJ, 860, 21

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Byun, W., Sheen, Y.-K., Ho, L. C., et al.: "KMTNet Nearby Galaxy Survey. I. Optimal Strategy for Low Surface Brightness Imaging with KMTNet", 2018, AJ, 156, 249

Calchi Novati, S., Skowron, J., Jung, Y. K., et al.: "Spitzer Opens New Path to Break Classic Degeneracy for Jupiter-mass Microlensing Planet OGLE-2017-BLG-1140Lb", 2018, AJ, 155, 261

Casewell, S. L., Braker, I. P., Parsons, S. G., et al.: "The first sub-70 min non-interacting WD-BD system: EPIC212235321", 2018, MNRAS, 476, 1405

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Chen, L., Kóspál, Á., Ábrahám, P., et al.: "A study of dust properties in the inner sub-au region of the Herbig Ae star HD 169142 with VLTI/PIONIER", 2018, A&A, 609, A45

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SAAO Staff

SAAO Executives

In the reporting period of April 2018 to March 2019, the SAAO Executive comprised the following:

Mr Chris Coetzee
Manager: SALT Operations

Mr Simon Fishley
Manager: Information & Technology

Mr Kevindran Govender
Director: IAU OAD

Mr Eugene Lakey
Manager: Finance and Operations

Mr Sivuyile Manxoyi
Manager: SALT Collateral Benefits Programme

Dr Stephen Potter
Head: Astronomy

Dr Encarni Romero Colmenero
Head: SALT Astronomy Operations

Dr Ramotholo Sefako
Head: Small Telescope Operations

Dr Amanda Sickafoose
Head: Instrumentation

Mrs Linda Tobin
Manager: Human Resources

Prof. Petri Väisänen
Director: SAAO

End of year 2018 - Aloha party

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This list includes casual staff, honorary fellows and students working at SAAO between April 2018 and March 201

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List of Acronyms

3D	Three Dimensional
ACT	Alan Cousins Telescope
AdvACT	Advanced Atacama Cosmology Telescope
AGB	Asymptotic giant branch
AGC	Asteroid Grand Challenge
AGN	Active galactic nucleus
AIMS	African Institute for Mathematical Sciences
AIO	African Intelligent Observatory
ALFA	Arecibo L-Band Feed Array
ALFALFA	Arecibo Legacy Fast ALFA
ALMA	Atacama Large Millimeter/sub-millimeter Array
ASSA	Astronomical Society of Southern Africa
ASSAf	Academy of Science of South Africa
ASAS-SN	All-Sky Automated Survey for SuperNovae
ASTMON	All-Sky Monitor
ATCA	Australia Telescope Compact Array
ATLAS	Asteroid Terrestrial-Impact Last Alert System
ATP	Acceptance Test Procedure
AUC	Area under curve
AURA	Association of Universities for Research in Astronomy
AVN	African Very long baseline interferometry Network
BCG	Brightest cluster galaxies
BiSON	Birmingham Solar Oscillations Network
CalTech	California Institute of Technology
CBNU	Chungbuk National University, Korea
CCD	Charge-coupled device
CDS	Astronomical Data Centre Strasbourg
CEO	Chief executive office
CfA	Center for Astrophysics
CNN	Cable News Network
CNN	Convolutional Neural Network
CSIC	Spanish Research Council
CTA	Cherenkov Telescope Array
DLR	The German Aerospace Center
DNN	Deep Neural Networks
DPT	Discrete Pulse Transform
DSI	Department of Science and Innovation
DST	Department of Science and Technology
ESO	European Southern Observatories
FLI	Finger Lakes Instrumentation
FLOYDS	Folded Low Order whYte-pupil Double-dispersed Spectrograph
FOV	field-of-view
FRI	Fanaroff-Riley class I
GAN	Generative Adversarial Neural
GFZ	German Research Centre for Geosciences
H2	molecular hydrogen
HESS	High Energy Stereoscopic System
HIPPO	HIgh speed Photo-Polarimeter
HST	Hubble Space Telescope
IAU	International Astronomical Union
INAF	National Institute for Astrophysics, Italy
IO	Intelligent Observatory
IRSF	InfraRed Survey Facility
IRTF	NASA Infrared Telescope Facility
IT	information technology
IUCAA	Inter-University Centre for Astronomy and Astrophysics
JWST	James Webb Space Telescope
KASI	Korean Astronomy and Space Science Institute
KELT-South	Kilodegree Extremely Little Telescope
KMTNet	Korea Microlensing Telescope Network
kNB	k-Nearest Neighbours
LADUMA	Looking At the Distant Universe with the MeerKAT Array
LCO	Las Cumbres Observatory
LIGO	Laser Interferometer Gravitational-wave Observatory
LIRGs	Luminous Infra-Red Galaxies
LJMU	Liverpool John Moores University
LMC	Large Magellanic Clouds
LSST	Large Synoptic Survey Telescope
LTS	Long Term Support)
MASTER	Mobile Astronomical System of the TElescope-Robots Network
MaxE	Maximum Efficiency spectrograph
MEARIM	Middle East and Africa Regional IAU Meetings
MIT	Massachusetts Institute of Technology
ML	machine learning

MLP	Multi Layer Perceptron
MNRAS	Monthly Notices of the Royal Astronomical Society
MONET	MOnitoring NEtwork of Telescopes
MORIS	MIT Optical Rapid Imaging System
MPG	Max Planck Society
MSc	Masters of Science
MWA	Multi-Wavelength Astronomy
NAOJ	National Astronomical Observatory of Japan
NASA	National Aeronautics and Space Administration
NASSP	National Astrophysics and Space Science Program
NB	Naive Bayes
NEO	near-Earth objects
NGC	National General Catalog
NIR	near-infrared
NOVA	Netherlands Research School for Astronomy
NRF	National Research Foundation
NSTF	National Science and Technology Forum
OAD	Office of Astronomy for Development
OGLE	Optical Gravitational Lensing Experiment
OSR	Optical Space Research
OSU	Ohio State University
PAC	postgraduate advisory committee
PRIME	PRime focus Infrared Microlensing Experiment
RESOLVE	REsolved Spectroscopy Of a Local VolumE
RF	Random Forest
RIRP	Research Innovation Reward Programme
RSS	Robert Stobie Spectrograph
SAAO	South African Astronomical Observatory
SAEON	South African Environmental Observation Network
SAGOS	South African Geodynamic Observatory Sutherland
SAHRA	South African Heritage Resources Agency
SAIP	South African Institute of Physics
SALT	Southern African Large Telescope
SARAO	South African Radio Astronomy Observatory
SCBP	SALT Collateral Benefit Programme
SDG	Sustainable Development Goals
SDSS	Sloan Digital Sky Survey
SETI	search for extraterrestrial intelligence
SKA	Square Kilometre Array
SHOC	Sutherland High-speed Optical Camera
SIRIUS	Simultaneous 3-colour InfraRed Imager for Unbiased Survey
SMART	Small Aperture Robotic Telescope
SMARTnet	Small Aperture Robotic Telescope Network
SMARTS	Small & Moderate Aperture Research Telescope System
SMC	Small Magellanic Cloud
SNR	signal-to-noise ratio
SOAR	Southern Astrophysical Research telescope
SOFIA	Stratospheric Observatory for Infrared Astronomy
SPIRITS	SPitzer InfraRed Intensive Transients Survey
SpUpNIC	Spectrograph Upgrade Newly-Improved Cassegrain
sSFR	specific star formation rate
SSR	SAAO student representative
STScI	Space Telescope Science Institute
SUMSS	Sydney University Molonglo Sky Survey
SUNBIRD	SUperNovae and starBurst in the InfraReD
SuperWASP	Super Wide Angle Search for Planets
TNO	trans-Neptunian objects
UC	University of Canterbury, New Zealand
UCSB	University of California, Santa Barbara
UCT	University of Cape Town
UV	ultraviolet
UW	University of Warsaw
UWC	University of the Western Cape
VHE	Very High Energy
VLA	Very Large Array
WFTC II	Wide Field Cryogenic Telescope

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