NRF
National Research Foundation

SAAO
South African Astronomical Observatory
200 YEARS

SAAO ANNUAL REVIEW 2019 | 2020

South African Astronomical Observatory

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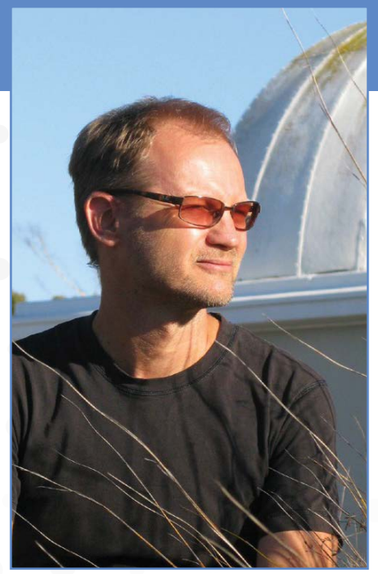


MESSAGE FROM THE SAAO DIRECTOR

With this Annual Review SAAO wishes to welcome you to the 2020s. For the Observatory this year means a full 200 years of existence as an astronomical institute. For astronomy as whole, the new decade promises to be ground-breaking - and the SAAO is intending to be right in the thick of it.

The occasion of SAAO's bicentenary on October 20, 2020 grants us the opportunity to recall many scientific achievements of the past decades and centuries. Some of these are elaborated on later in this issue. However, it needs to be acknowledged that this past is also a troubled one. I believe this occasion is an opportunity to look forward "Beyond 200 Years of Astronomy", celebrate together our country's and our continent's rich and diverse cultural heritage, scientific heritage included, and make sure the biases of the past are actively redressed. We at SAAO see this future full of opportunity, inclusivity, inspiration, and pride in the excellence of decidedly African Astronomy at the forefront of a cutting-edge global pursuit of exploring our Universe.

Astronomy in the 2020s is entirely global. Astronomy cannot be done merely at a national level simply because the infrastructure requirements to pursue the cutting-edge scientific questions of today are larger and more expensive than a typical country's resources are. The decade brings forth a new generation of giant 20-40m optical telescopes, the revolutionary Vera Rubin Observatory (formerly LSST), JWST, PLATO, and the Nancy Grace Roman Space Telescope (formerly WFIRST) among several NASA or ESA space telescopes, and of course the SKA here in South Africa. Topics and questions pursued with these exciting projects range from Exoplanets to galaxy evolution and the fundamental physics of the cosmos through the study of transients, changing events on the night-sky, at a scale not seen before.

SAAO scientists are involved and engaged in these world-wide trends, developments and projects.

An aspect to which we especially aim to contribute to is transient science. A particular strength of ours lies in the unique Sutherland observing site with its vast instrumentation suite, which we plan to network into a single autonomously working "machine" which reacts flexibly, rapidly, and intelligently to the massive data deluge expected from the new facilities mentioned above. We have dubbed the project the Intelligent Observatory (IO) initiative. It has already kicked off as described later in this issue, though it will still take many years to reach the level we envision.

The IO is a core element of the SAAO vision of the 2020s. Another core element of the SAAO vision, as we come to the bicentennial, is growing a vibrant national scientific community through training, education, and science awareness, on the way to fulfilling the promise of African Astronomy.

And that vision would not be possible without the part played by every one of the exceptionally skilled and passionate staff members at SAAO. I hope you will get a taste of what our staff and students do in the many different domains and functions of the organisation in the articles of this Annual Review 2019/2020.

Prof. Petri Väisänen

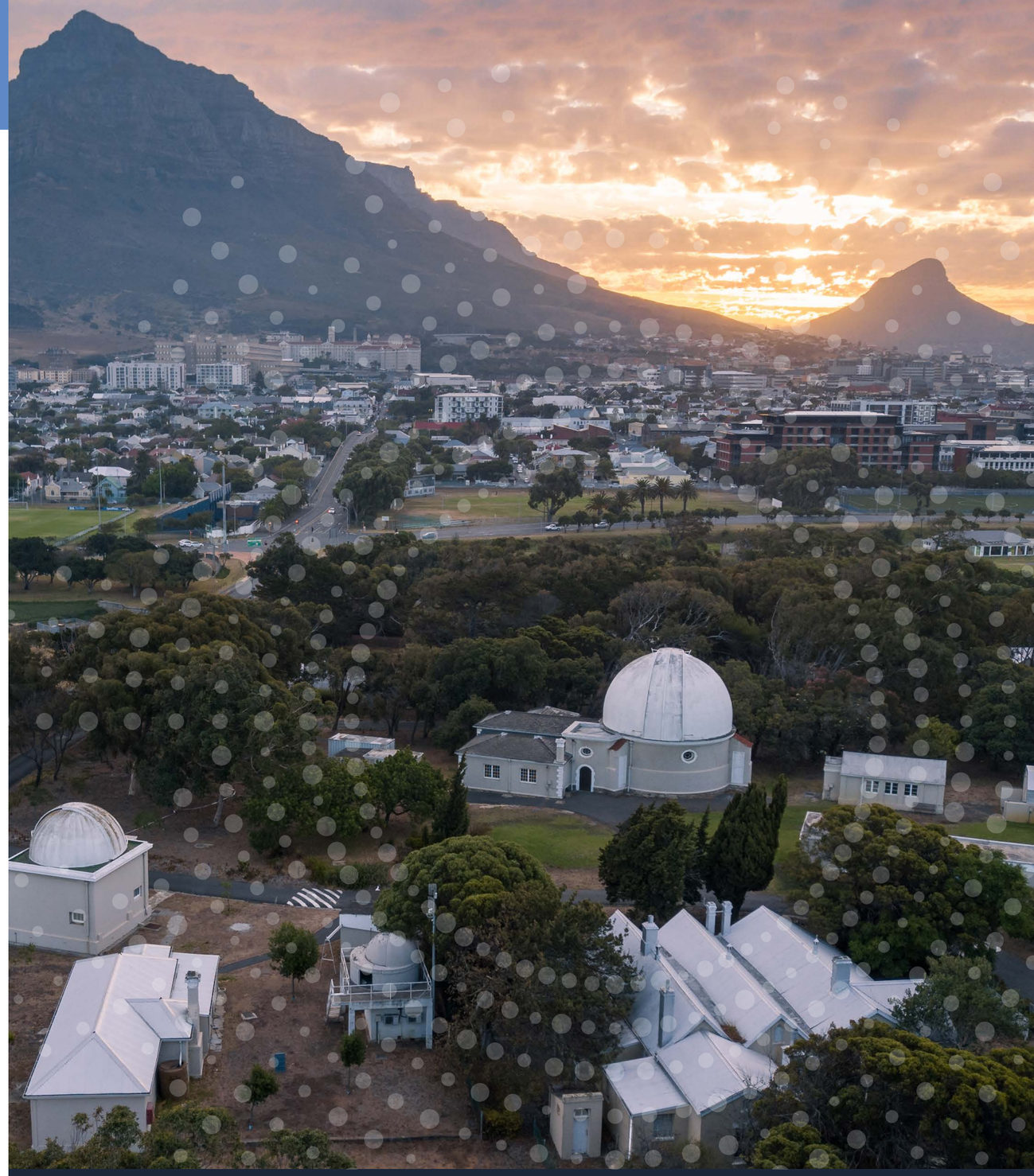
MESSAGE FROM THE DEPUTY CEO OF THE NATIONAL RESEARCH FOUNDATION

This year the South African Astronomical Observatory, the South Africa's premier optical and infrared astronomy facility, and a National Research Facility under the NRF, celebrates its 200th year.

As we reflect on the past year's results we are cognisant that they represent just a fraction of the myriad achievements of the past two centuries and an intriguing taste of the exciting advancements to come. Primary amongst such expectations are the exciting scientific opportunities to emerge out of the establishment of the Square Kilometre Array and the breakthroughs we anticipate from multi-messenger astronomy research approaches involving SAAO's flagship research platform, SALT. As per the NRF's Vision 2030 strategic framework, it is envisaged that these developments will help cement the NRF's strategic intent of being the premier Science organization in the country.

National Research Foundation

Dr. Clifford Nxomani



ABOUT SAAO

ABOUT SAAO

Founded in 1820, the SAAO is the national centre for optical and infrared astronomy in South Africa. Its primary role is to conduct fundamental research in astronomy and astrophysics by providing a world-class facility to scientists.

The SAAO also promotes astronomy and astrophysics in Southern Africa, by sharing research findings and discoveries, and participating in education and outreach activities to inform and enthuse citizens about physics and astronomy.

The South African Astronomical Observatory (SAAO) is a business unit of the National Research Foundation(NRF) and a National Research Facility which operates under the mandate of the Department of Science and Innovation (DSI).

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.

SAAO's headquarters are 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 from 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.

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 (over 13 million Rand) 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 its 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 table). 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.

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

OAD
OFFICE OF ASTRONOMY FOR DEVELOPMENT

NRF National Research Foundation

SAAO South African Astronomical Observatory 200 YEARS

The bicentenary of the South African Astronomical Observatory

This year, 2020, marks the bicentenary of the South African Astronomical Observatory (SAAO). Founded on 20 October 1820, the Royal Observatory is the oldest scientific institution in the country and perhaps in sub-Saharan Africa.

When founded, the Royal Observatory was controlled by the Royal Navy and was intended for the improvement of navigation. Its main duty was to chart the southern skies and provide a time service for passing ships. A few years after completion, the observatory became known for a number of fundamental discoveries that were made. These discoveries were not only significant for astronomy but also in that they brought astronomy in Africa onto the global stage.

Given its international scientific significance, the SAAO campus was the subject of a UNESCO World Heritage Site report. It was officially declared a National Heritage Site on 21 December 2018, by the South African Heritage Resources Agency (SAHRA), in accordance with Section 27 (1) of the "National Heritage Resources Act" (NHRA), No.25 of 1999. This declaration will ensure that the treasure trove of heritage materials, and knowledge assets the SAAO holds, are preserved for future generations for both the knowledge and cultural enterprises of our country.

In light of its bicentenary, the SAAO is planning various events in 2020, including the unveiling of the site as a National Heritage Site and a Virtual Astronomy Symposium.

10 MAJOR CONTRIBUTIONS TO ASTRONOMY FROM THE OBSERVATORY

The first observations that led to the distance determination of a star (Alpha Centauri) were made in 1832-33 by Thomas Henderson. The current nearest star, Proxima Centauri was discovered in 1915 by Robert Thorburn Ayton Innes who had worked previously with Sir David Gill at the Royal Observatory.

Frank McClean, a wealthy British amateur astronomer, discovered the element Oxygen in stars using the Astrographic Telescope at the Royal Observatory. In 1905 Joseph Lunt, who was one of the assistants, demonstrated the presence of Silicon and Europium in the spectra of the stars.

John Franklin-Adams was a British amateur astronomer who was responsible for the first photographic atlas of the whole sky. In 1903, the Southern part of his survey commenced at the Royal Observatory. It was completed in Johannesburg.

Sir David Gill's value for the distance between the Earth and the Sun was determined from the Royal Observatory and was regarded as the best available for 45 years.

After receiving an amateur photograph of the Great Comet of 1882, Gill realised that photography was an ideal technique for mapping the sky. During his time as the director of the Royal Observatory, he pioneered the first sky survey and was the co-leader of the Astrophotographic Congress, the first international astronomical congress, in 1887.

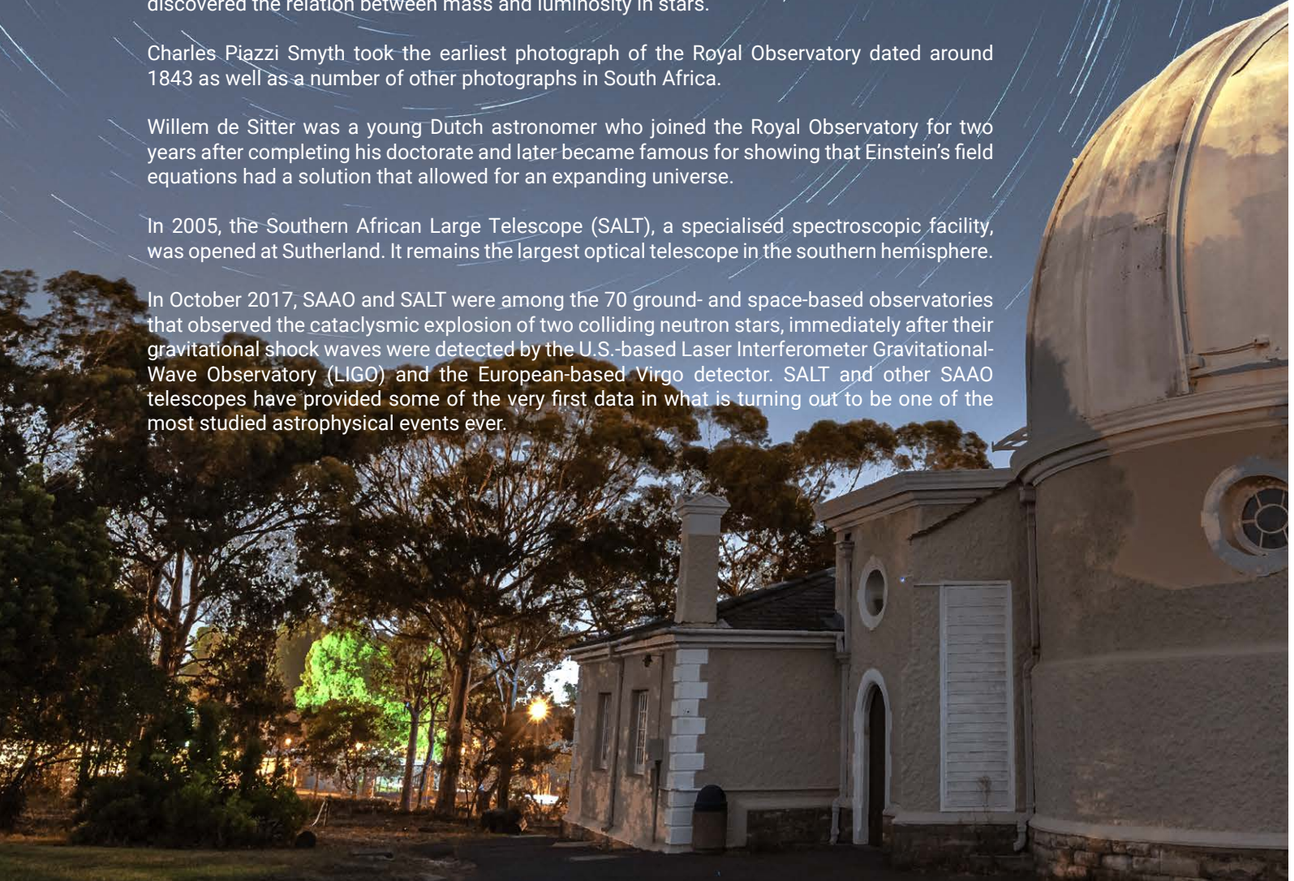
Joseph Halm, who was the chief assistant, was a pioneer of stellar dynamics and also discovered the relation between mass and luminosity in stars.

Charles Piazzi Smyth took the earliest photograph of the Royal Observatory dated around 1843 as well as a number of other photographs in South Africa.

Willem de Sitter was a young Dutch astronomer who joined the Royal Observatory for two years after completing his doctorate and later became famous for showing that Einstein's field equations had a solution that allowed for an expanding universe.

In 2005, the Southern African Large Telescope (SALT), a specialised spectroscopic facility, was opened at Sutherland. It remains the largest optical telescope in the southern hemisphere.

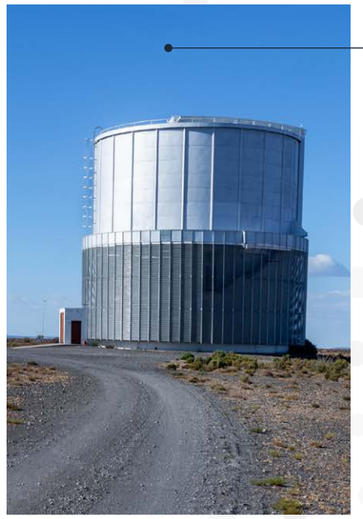
In October 2017, SAAO and SALT were among the 70 ground- and space-based observatories that observed the cataclysmic explosion of two colliding neutron stars, immediately after their gravitational shock waves were detected by the U.S.-based Laser Interferometer Gravitational-Wave Observatory (LIGO) and the European-based Virgo detector. SALT and other SAAO telescopes have provided some of the very first data in what is turning out to be one of the most studied astrophysical events ever.



SAAO TELESCOPES

SALT (Southern African Large Telescope)

Size: 9 x 11 m
Spectrographs (low and high resolution), CCD camera, Spectro-polarimeter
Start of science operations: 2011



1.9-metre

Size: 1.9 m
Spectrographs, CCD cameras, Polarimeter
Start of science operations: 1938-1948

Lesedi

Size: 1.0 m
CCD cameras, spectrograph coming soon
First light: 2016

1.0-metre

Size: 1.0 m
CCD cameras
Start of science operations: 1964

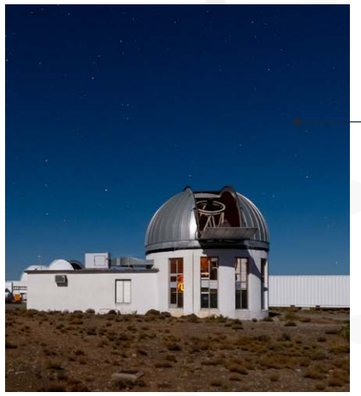
DIMM

Sky monitor, part of SALT

ACT (Alan Cousins Telescope)

Size: 0.75 m
Photometer
Start of science operations: 1999

SAAO CO-OWNED FACILITIES



IRSF (InfraRed Survey Facility)

Size: 1.4 m

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

IRSF has been a fruitful collaboration between Japan and SAAO since 2000 and offers a near-infrared camera (SIRIUS) and polarimeter (SIRPOL).

MeerLICHT

Size: 0.65 m

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

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

BiSON (Birmingham Solar Oscillations Network)

Size: 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)

Size: 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)

Size: 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)

Size: 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)

Size: 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

Size: 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)

Size: 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.

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

Size: 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. The network comprises five ASAS-SN telescopes.

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

Size: 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.

bRing Project (ß Pic b ring)

Size: 2 x 2.4 cm f/1.4 wide field lenses

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

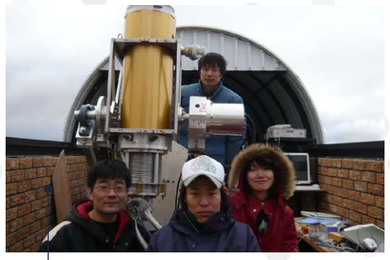
The bRing experiment consists of a twin/two-camera telescope, monitoring the bright star β Pictoris for signs of obscuration from circumplanetary dust associated with the young gas giant exoplanet β Pic b.

Xamidimura

Size: 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)

Size: 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.

ASTMON 2 fish-eye photo lenses

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

SANSA facility

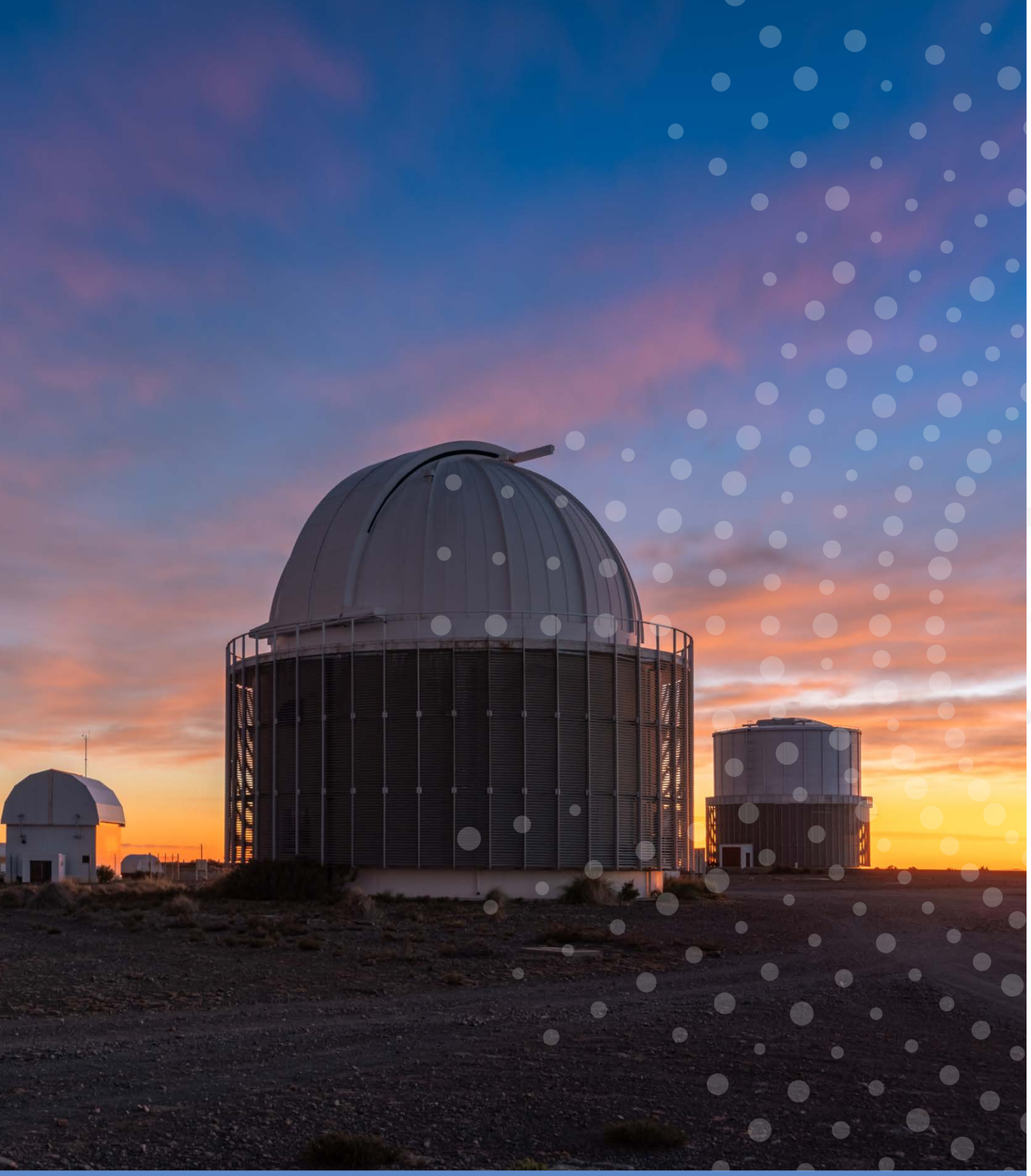
SANSA

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.

SAGOS (South African Geodynamic Observatory Sutherland)

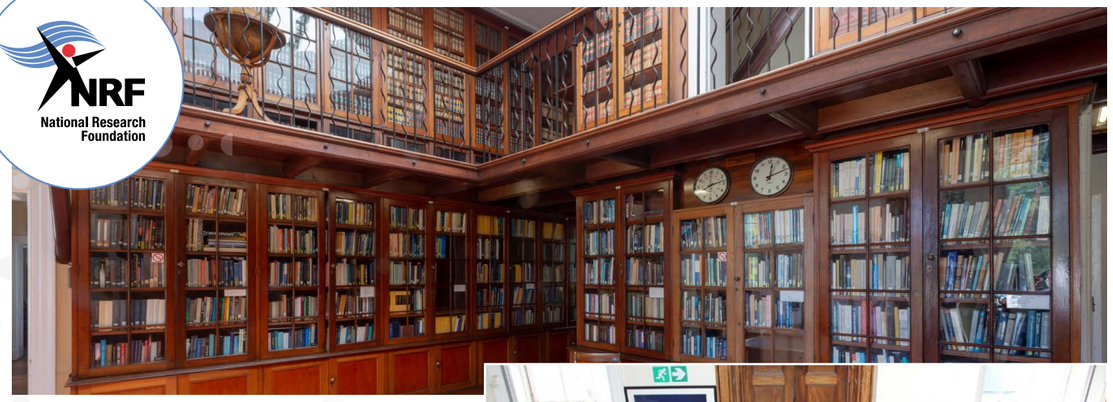
German Research Centre for Geosciences (GFZ)

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



SAAO **NEWS**

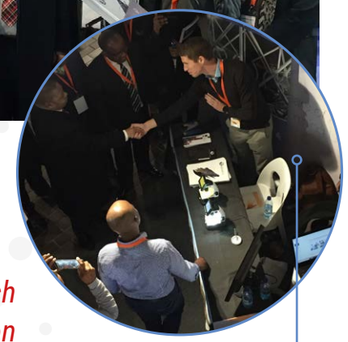
SAAO STAFF CELEBRATES NRF'S 20TH BIRTHDAY



On the 1st of April 2019, the National Research Foundation (NRF) celebrated its 20th birthday. On this day, the SAAO staff gathered in the main library and Cape Town to commemorate the NRF's 20th anniversary. SAAO director, Prof Petri Väisänen said a few words and staff further celebrated by singing happy birthday to the NRF.

Staff were treated to specially designed NRF20 cupcakes to celebrate 20 years of Advancing Knowledge, Transforming Lives and Inspiring a Nation and each staff member was presented with a commemorative NRF20 Shirt to mark the occasion.

The NRF staff with the Hon. Dr Blade Nzimande



Daniel and the minister's meet and greet

The National Research Foundation (NRF) exhibition stood out, catering for all of the facilities that form part of the NRF.

DST BUDGET VOTE

As part of the 2019 Parliamentary Budget Vote, the SAAO, along with other science and technology entities, were invited to set up their exhibitions at the Iziko South African Museum on the 9 July 2019. The National Research Foundation (NRF) exhibition stood out, catering for all of the facilities that form part of the NRF. In addition to the SAAO, the three other organisations that had set up their exhibitions were the South African Environmental Observation Network (SAEON), iThembaLabs, and the South African Radio Astronomy Observatory (SARAO).

Representing the SAAO were Ms Thabisa Fikelepi and Dr Daniel Cunnama. Deputy CEO of the NRF Dr Clifford Nxomani and other NRF executives were also present to represent the NRF. Dr Cunnama together with the executives and employees were able to meet and greet the new Minister of Higher Education, Science & Innovation, The Honourable Dr Blade Nzimande and demonstrate the various exhibitions.

THE CHANGING LANDSCAPE OF SOUTH AFRICAN ASTRONOMY

South Africa is looking forward to hosting the **International Astronomical Union (IAU) General Assembly in 2024** — for the first time on the African continent. The meeting will come at a time of burgeoning scientific prosperity for the growing community of indigenous South African and African astronomers.

Some of the recent South African PhD graduates, three of whom came through the NASSP programme, who are now early-career astronomers at the SAAO

SAAO Astronomer, Dr David Buckley, published an article in the prestigious Nature Astronomy journal on the changing landscape of South African astronomy, highlighting the huge strides made in the development of astronomy in South Africa and on the continent as a whole in recent decades; providing some perspectives on the future of astronomy on the continent:

"The African continent has seen enormous strides in astronomy development over the last ~2 decades, not least being the construction of three major internationally recognized facilities. First came the European-led High Energy Stereoscopic System (HESS), a ground-based Cherenkov TeV gamma-ray telescope array in Namibia, which began operations in 2002.

The 10-m class Southern African Large Telescope (SALT), still, the largest single optical telescope in the Southern Hemisphere, was completed in 2005 and is situated at the Sutherland site of the South African Astronomical Observatory (SAAO), which itself was established in 1972.

Finally, the MeerKAT radio telescope array situated near the remote Karoo town of Carnarvon, one of the Square Kilometre Array (SKA) pathfinders and now a precursor to SKA Phase 1, was inaugurated in July 2018."

Link to article: https://rdcu.be/bAxLO

SCIENCE4DEV WORKSHOP

Delegates discussed Science for Development

A workshop entitled "Science 4 Development: building bridges between disciplines" was held at the SAAO on 30 & 31 January 2020. The workshop, which brought together around 100 participants from 25 different countries, was hosted by the International Astronomical Union's Office of Astronomy for Development (OAD) and the International Science Council's Regional Office for Africa, together with several other partners.

Participants included researchers, industry leaders and communicators from across disciplines. The experimental workshop aimed at stimulating conversations and collaborations to find ways that science can effectively aid in socio-economic development. It featured talks, panel discussions as well as less conventional interaction methods such as lightning presentations and unconference sessions.

In order to encourage practical solutions and projects that could be taken forward beyond the conference, participants pitched a project idea for a small financial prize. These projects could be interrogated by other participants, and jointly worked on during "hack sessions".

The winning proposal was for a multi-disciplinary Honours level course on "Science for Development", aimed at engaging science students in an understanding of the bigger picture of development, familiarity with development concepts and practices, and an ability to translate their science skills into a broader sustainable development context. The proposal was pitched by Assoc. Prof. Carolina Odman of the Inter-University Institute for Data-Intensive Astronomy, based at the University of the Western Cape.

*More information on the workshop can be found online at **www.science4dev.org***

PARLIAMENTARY PORTFOLIO COMMITTEE VISIT

On the 4th of March 2020, the SAAO was honoured to host the Parliamentary Portfolio Committee on Higher Education Science and Technology in Cape Town. In addition to the Committee, the event was attended by representatives of the National Research Foundation, the SAAO Executive and scientists, engineers and students from the SAAO.

Prof Petri Vaisanen presented on the SAAO's achievements to date and the "Vision of Astronomy in the next decade: globally connected science working for South African Society.

There were also presentations by Mr Anthony Mietas on the Socio-economic impact of the SAAO and SALT in Sutherland and by Dr Vanessa McBride on the Office of Astronomy for Development and the various projects carried out by their team. Finally, the committee was treated to a tour of the SAAO facility, including the electronic and mechanical workshops as well as the museum and McClean building.

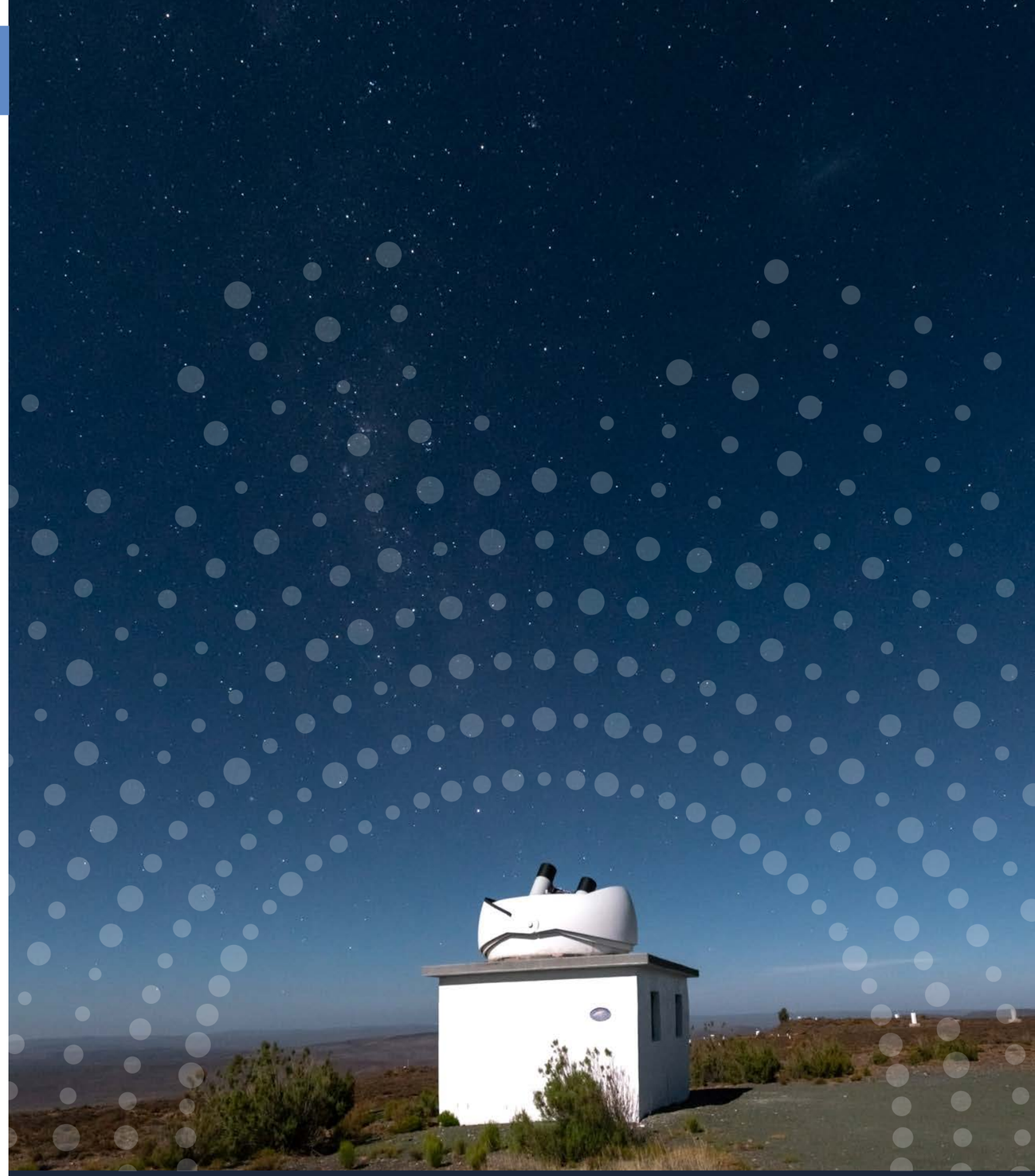
The committee was thoroughly engaged throughout the visit asking many questions and particularly enjoyed the moving floor of the McClean telescope!

TRANSIENTS 2020

The International co-ordination of multi-messenger transient observations in the 2020s and beyond (https://kavlitransients2020.saao.ac.za/), was an international workshop sponsored by the Kavli Foundation under the auspices of the IAU Executive Committee Working Group on Coordination of Ground and Space Astrophysics (https://www.iau.org/science/scientific_bodies/working_groups/278/).It was held at SAAO from 3 to 7 February 2020 and involved over 50 people from 18 countries and 6 continents, representing most of the world's observatories, projects and collaborations involved in multi-messenger transient astronomy.

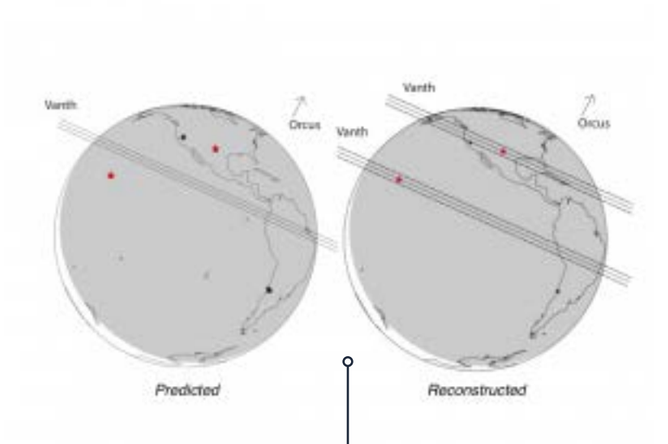
The objective was to explore the challenges in making international multi-messenger collaborations function and to draft a white paper with recommended best practice. Multi-messenger astronomy combines observations across the electromagnetic spectrum with neutrino and gravitational-wave measurements and of course links observations with theory. The Scientific Organizing Committee was co-chaired by Patricia Whitelock (SAAO and UCT, who also chaired the Local Organizing Committee) and Brad Cenko (NASA, USA). The detailed programme (https://kavlitransients2020.saao.ac.za/program/) includes links to most of the presentation given.

Various subsidiary events were held in conjunction with the workshop. Ewine van Dishoeck (Netherlands), President of the IAU, gave public talks at the Universities of the Western Cape (UWC) and Cape Town (UCT) she also had a meeting with the young women astronomers, including students. Ben Stappers (UK) gave a Saturday evening public talk at SAAO and Karina Leppik gave one at the African Institute of Mathematical Sciences (AIMS). Jamal Mimouni (Algeria), Anna Franckowiak (Germany) and Karina Leppik (USA) visited schools around the peninsula and talked to learners, as arranged by the SALT Collateral Benefits Division. Several of the astronomers visited Sutherland over the following weekend where they saw SALT and MeerLICHT in operation as well as getting a tour of the town, including the community centre.

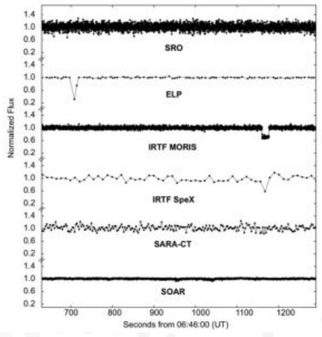


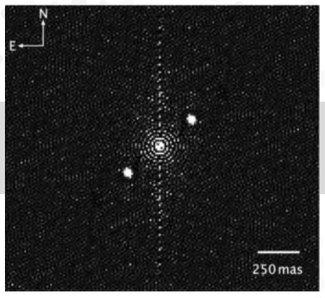
SCIENCE HIGHLIGHTS

A MYSTERY IN THE OUTER SOLAR SYSTEM



Top: Predicted path of Vanth's shadow for the 07 March 2017 occultation. Right: Reconstructed path, after obtaining confirmation of the visual double-star from Gemini. In each plot, the three lines represent the north, middle, and south extent of the shadow. The observing sites are marked by stars, with successful sites in red. Orcus' shadow was well off the globe to the north and the error bars were approximately half the size of the Earth.





Stellar occultations are a powerful technique that allows characterisation of foreground objects by watching them block light from a distant star. This technique is particularly useful for studying small and/or distant objects in the Solar system, which are difficult to see from the ground.

In March 2017, a team of astronomers from SAAO and the Massachusetts Institute of Technology observed a stellar occultation that was predicted for a large Trans-Neptunian Object named Orcus.

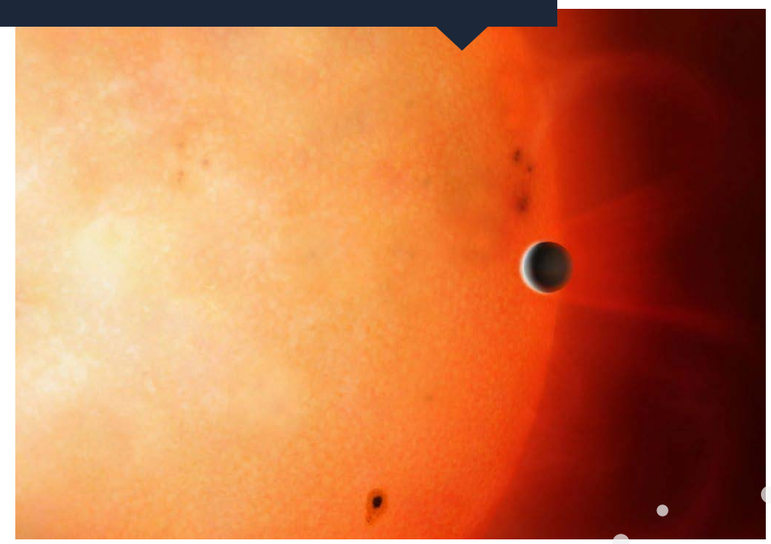
Prior to this observation, Orcus was known to be approximately 900 km in size, Prior to this observation, Orcus was known to be approximately 900 km in size, having one satellite, Vanth, with a size of roughly 280 km. The Orcus system is in a 3:2 orbital resonance with Neptune, similar to Pluto's orbit. Although not expected to maintain an atmosphere, Orcus' features hinted toward a possible resurfacing mechanism such as cryovolcanism. Goals of the occultation observation included accurately constraining Orcus' size, measuring any atmosphere around Orcus, and detecting rings or debris in the system.

Five sites in America attempted the observation, with locations spanning from Chile to northern California. Two sites successfully detected the star disappearing: NASA's 3-m Infrared Telescope Facility (IRTF) on Mauna Kea, Hawaii, and a 1-m Las Cumbres Observatory (LCO) telescope at McDonald Observatory, Texas. However, a quick analysis of the geometry and the timing showed that data did not align with the expectation of one star being occulted by one outer Solar system object. After months of careful study, the best guess was that one site observed an occultation by Vanth of the target star while the second site observed an occultation by Orcus of an unknown secondary star.

To definitively solve the mystery, the background star was observed with the Differential Speckle Survey Instrument (DSSI) at the 8.1-m Gemini South telescope in Chile. The high-resolution images easily detected a companion star 250 milliarcseconds away from the brighter primary. Armed with confirmation of the location of the second star, the occultation data were reanalysed to reveal that both detections were of Vanth, each blocking one of the two separate stars (right-hand panel in the figure). The data now allowed Vanth's size to be measured at 443±10 km in diameter, much larger than predicted. They also placed a constraint of a few microbars on any global Vanth atmosphere and did not detect any material in the two-star paths down to a limit of a few kilometres in extent.

Reference:
Sickafoose, A.A., et al 2019/02, Icarus 319, 657: A stellar occultation by Vanth, a satellite of (90482) Orcus. https://doi.org/10.1016/j.icarus.2018.10.016

SAAO 1.0M TELESCOPE PIVOTAL IN THE DISCOVERY OF A 'FORBIDDEN' PLANET IN THE 'NEPTUNIAN DESERT'



The SAAO's 1.0m telescope provided crucial follow-up observations in research published by members of the Astronomy and Astrophysics Group at the University of Warwick, UK, detailing the discovery of an exoplanet in the so-called "Neptunian Desert".

The planet NGTS-4b, also nick-named 'The Forbidden Planet' by researchers is about 20 times the mass of the Earth and about 3 times the size. The planet orbits its host star in just 1.3 days with temperatures exceeding 1000 degrees Celsius.

NGTS-4b was first noticed using the state-of-the-art Next-Generation Transit Survey (NGTS) observing facility, designed to search for transiting planets on bright stars. NGTS is situated at the European Southern Observatory's Paranal Observatory in the heart of the Atacama Desert, Chile.

The discovery relied heavily on follow-up observations made by Dr Matt Burleigh (University of Leicester) using the Sutherland High-speed Optical Cameras (SHOC) on the SAAO 1.0m Telescope in November 2017. This triggered an international effort to obtain further observations and a few weeks later it was confirmed that the transit was indeed a sub-Neptune exoplanet.

The planet NGTS-4b, also nick-named 'The Forbidden Planet' by researchers is about 20 times the mass of the Earth and about 3 times the size.

When looking for new planets astronomers look for a dip in the light of a star – this is the planet orbiting it and blocking the light. Usually, only dips of greater than 1% are picked up by ground-based searches, but the NGTS telescopes can pick up a dip of just 0.1%. With a dip almost that small, this exoplanet is, by a long way, the shallowest transiting planet ever discovered by a ground-based survey (the transit is less than 0.2%).

Dr Burleigh explained "Since this transit is so shallow, NGTS-4b wasn't initially one of our top priority targets. But thanks to the excellent telescopes at SAAO Sutherland, we were able to detect and confirm the transit, convincing ourselves the planet is real. We then set in motion many more observations to measure its mass and size."

It is the first exoplanet of its kind to have been found in the Neptunian Desert, which is the region close to stars where, up until now, no Neptune-sized planets have been found. This area receives strong irradiation from the star, meaning the planets do not retain their gaseous atmosphere as they evaporate leaving just a rocky core. However, NGTS-4b still has its atmosphere of gas leading researchers to believe the planet may have moved into the Neptunian Desert recently, in the last one million years or that it was originally very big and the atmosphere is still evaporating.

Reference:
West, R.G., et al 2019/04, MNRAS 486, 5094: NGTS-4b: A sub-Neptune transiting in the desert. https://doi.org/10.1093/mnras/stz1084

REPEATING OUTFLOWS OF HOT WIND FOUND CLOSE TO A GALACTIC BLACK HOLE

"What was particularly unusual about this system was that ground-based telescopes had revealed that its optical brightness displayed periodic dips in its output and that the period of these dips slowly changed from around 2 mins to about 10 mins as the outburst evolved. Such strange behaviour has never been seen in any other object."

An international team of astrophysicists from Southampton, Oxford and South Africa detected a very hot, dense outflowing wind close to a black hole at least 25,000 light-years from Earth.

Lead researcher Professor Phil Charles from the University of Southampton, and former director of the SAAO, explained that the gas (ionised helium and hydrogen) was emitted in bursts which repeated every 8 mins, the first time this behaviour has been seen around a black hole. The findings have been published in the journal Monthly Notices of the Royal Astronomical Society.

The object Professor Charles' team studied was Swift J1357.2-0933 which was first discovered as an X-ray transient – a system that exhibits violent outbursts – in 2011. These transients all consist of a low-mass star, similar to our Sun, and a compact object, which can be a white dwarf, neutron star or black hole. In this case, Swift J1357.2-0933 has a black hole compact object which is at least 6 times the mass of our Sun.

Material from the normal star is pulled by the compact object into a disc in between the two. Massive outbursts occur when the material in the disc becomes hot and unstable and it releases copious amounts of energy.

Professor Charles said: "What was particularly unusual about this system was that ground-based telescopes had revealed that its optical brightness displayed periodic dips in its output and that the period of these dips slowly changed from around 2 mins to about 10 mins as the outburst evolved. Such strange behaviour has never been seen in any other object.

"The cause of these remarkable, fast dips has been a hot topic of scientific debate ever since their discovery. So it was with great excitement that astronomers greeted the second outburst of this object in mid-2017, presenting an opportunity to study this strange behaviour in greater detail."

Professor Charles and his team recognised that key to getting the answer was to obtain optical spectra a number of times during each dipping cycle, essentially studying how their colour changed with time. But with the object, about 10,000 times fainter than the faintest star visible to the naked eye and the dip period of only around 8 minutes, a very big telescope had to be used.

So, they used SALT, the Southern African Large Telescope, the largest optical telescope in the southern hemisphere.

The University of Southampton is one of the founding UK partners in SALT, and together with their South African collaborators, are part of a multi-partner Large Science Programme to study transients of all types. Not only does SALT have the necessary huge collecting area (it has a 10m diameter mirror), but it is operated in a 100% queue-scheduled way by resident staff astronomers, meaning that it can readily respond to unpredictable transient events. This was perfect for Swift J1357.2-0933, and SALT obtained more than an hour of spectra, with one taken every 100 secs.

"Our timely observations of this fascinating system demonstrates how the quick response of SALT, through its flexible queue-scheduled operation, makes it an ideal facility for follow-up studies of transient objects", said Dr David Buckley, the Principal Investigator of the SALT transient programme, based at the SAAO, who also added, "With the instantaneous availability of a number of different instruments on SALT, we can also dynamically modify our observing plans to suit the science goals and react to results, almost in real-time".

Professor Charles added: "The results from these spectra were stunning. They showed ionised helium in absorption, which had never been seen in such systems before. This indicated that it must be both dense and hot – around 40,000 degrees. More remarkably, the spectral features were blue-shifted (due to the Doppler effect), indicating that they were blowing towards us at about 600km/s. But what really astonished us was the discovery that these spectral features were visible only during the optical dips in the light-curve. We have interpreted this quite unique property as due to a warp or ripple in the inner accretion disc that orbits the black hole on the dipping timescale. This warp is very close to the black hole at just 1/10 the radius of the disc."

What is driving this matter away from the black hole? It is almost certainly the radiation pressure of the intense X-rays generated close to the black hole. But it has to be much brighter than we see directly, suggesting that the material falling on to the black hole obscures it from direct view, like clouds obscuring the Sun. This occurs because we happen to be viewing the binary system from a vantage point where the disc appears edge-on, as depicted in the schematic illustration, and rotating blobs in this disc obscure our view of the central black hole.

Interestingly there are no eclipses by the companion star seen in either the optical or X-ray as might be expected. This is explained by it being very small, and constantly in the shadow of the disc. This inference comes from detailed theoretical modelling of winds being blown off accretion discs that was undertaken by one of the team, James Matthews at the University of Oxford, using supercomputer calculations.

This object has remarkable properties amongst an already interesting group of objects that have much to teach us about the end-points of stellar evolution and the formation of compact objects. We already know of a couple of dozen black hole binary systems in our Galaxy, which all have masses in the 5-15 solar mass range, and the single black hole at our Galactic Centre is around 4 million solar masses. They all grow by the accretion of matter that we have witnessed so spectacularly in this object. We also know that a substantial fraction of the accreting material is being blown away. When that happens from the supermassive black holes at the centres of galaxies, those powerful winds and jets can have a huge impact on the rest of the galaxy.

These short-period binary versions are a perfect way to study this physics in action.

Reference:
Charles, P., et al 2019/07, MNRAS 489, L47: Hot, dense He ii outflows during the 2017 outburst of the X-ray transient Swift J1357.2−0933.
https://doi.org/10.1093/mnrasl/slz120

SAAO AND MEERKAT COMBINE TO CONFIRM THE DETECTION OF A FLARING BLACK HOLE

Researchers from the SAAO have utilised the South African Radio Astronomy Observatory MeerKAT Telescope to confirm the existence of a never-before-seen flaring black hole.

The European Space Agency's (ESA) XMM-Newton X-ray space telescope recently discovered mysterious X-ray flashes from the active black hole at the core of the galaxy GSN 069, some 250 million light-years away.

On 24 December 2018, the object was seen to suddenly increase its brightness by up to a hundred times, then dimmed back to its normal levels within one hour and lit up again nine hours later.
"It was completely unexpected," says Giovanni Miniutti, of the Centro de Astrobiología in Madrid, Spain, lead author of the paper published in the prestigious journal, Nature.

"Giant black holes regularly flicker like a candle but the rapid, repeating changes seen in GSN 069 from December onwards is something completely new." "The X-ray emission comes from material that is being accreted onto the black hole and heats up in the process," explains Giovanni.

Although never before observed, Giovanni and colleagues think periodic flares like these might actually be quite common in the Universe. It is possible that the phenomenon hadn't been identified before because most black holes at the cores of distant galaxies, with masses millions to billions of times the mass of our Sun, are much larger than the one in GSN 069, which weighs about 400,000 times our Sun.

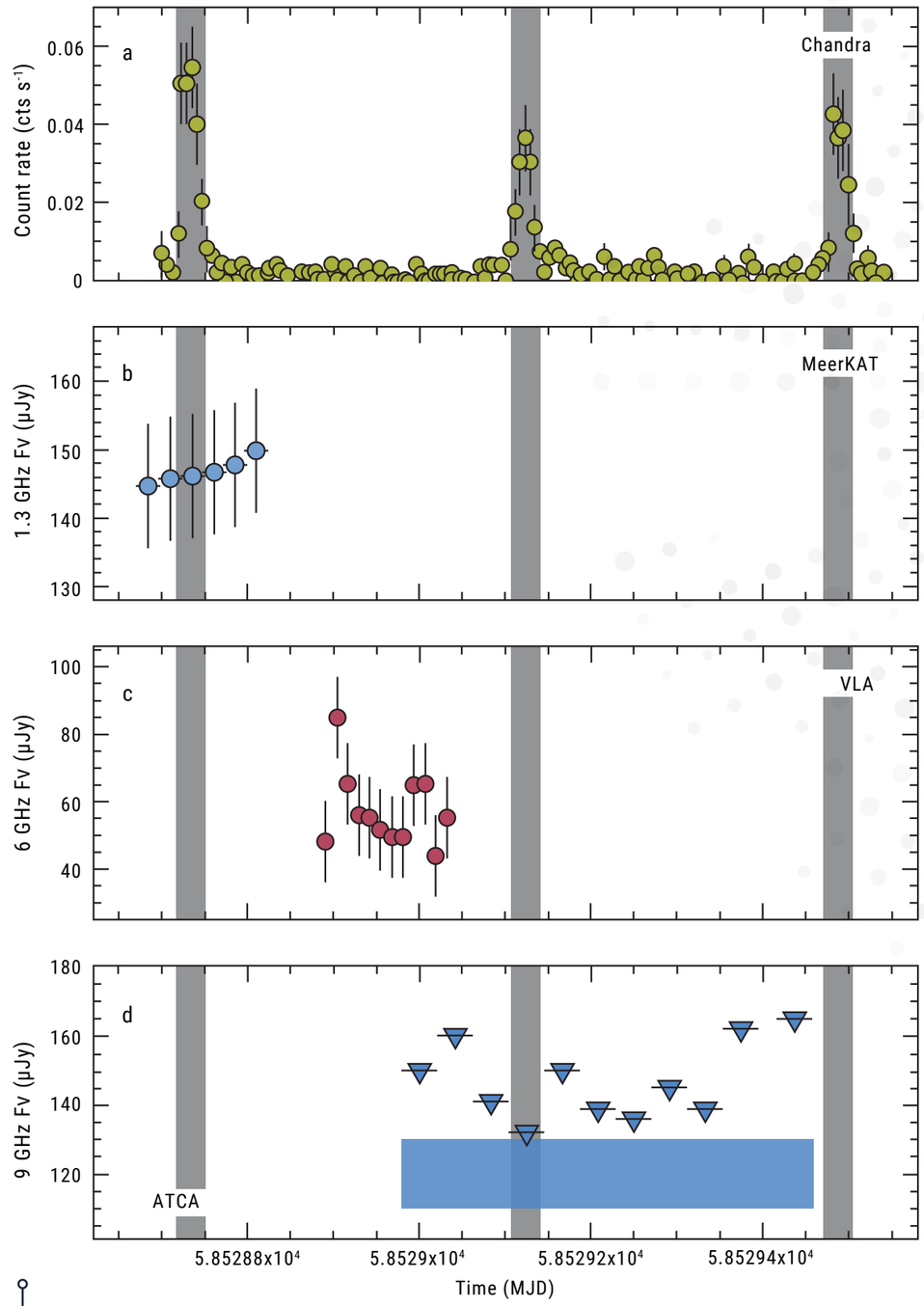
In order to study the radio properties of the source of these X-ray flashes, astronomers from the SAAO used the powerful new capabilities provided by their sister NRF Facility, the SARAO.

SAAO Astronomers Dr Retha Pretorius and Dr Itumeleng Monageng utilised SARAO's MeerKAT Radio telescope and were able to detect the black hole at lower frequencies (1.3GHz) to complement other radio observations from ATCA (5.5 and 9 GHz) and VLA (6 GHz).

"Having access to such a powerful radio telescope has enabled us to compete internationally on major discoveries like this, MeerKAT is yet another world-class telescope available to South African astronomers" said Dr Monageng.

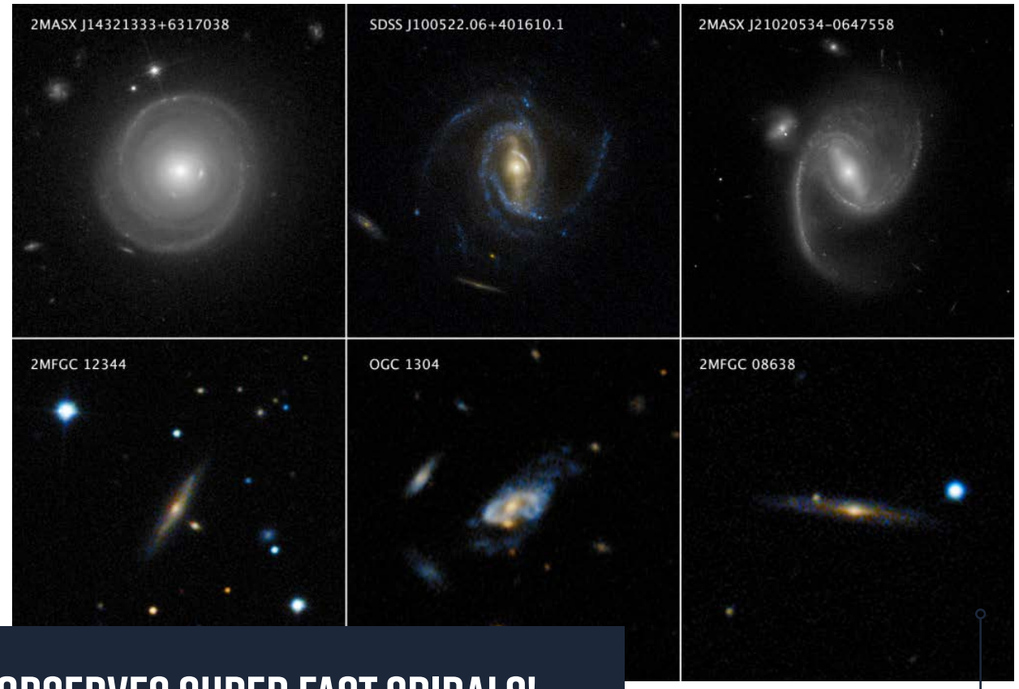
SARAO Director Rob Adam added "It's exciting to see MeerKAT being used in a groundbreaking multi-wavelength study by young South African researchers from our sister observatory".

Reference:
Miniutti, G., et al 2019/09, Nature 573, 381: Nine-hour X-ray quasi-periodic eruptions from a low-mass black hole galactic nucleus. https://doi.org/10.1038/s41586-019-1556-x



From top to bottom, the Chandra, MeerKAT, VLA, and ATCA light curves as obtained during the 2019 February 14/15 X-ray/radio campaign. No significant radio variability appears to be associated with X-ray eruptions. This is a crucial piece of information for interpreting the QPE phenomenon. [credit: G. Miniutti]

"Nine hour X-ray quasi-periodic eruptions from a low mass black hole galactic nucleus," by G. Miniutti et al. is published in Nature https://www.nature.com/articles/s41586-019-1556-x



The top row of this mosaic features Hubble images of three spiral galaxies, each of which weighs several times as much as the Milky Way. The bottom row shows three even more massive spiral galaxies that qualify as "super spirals," which were observed by the ground-based Sloan Digital Sky Survey. Super spirals typically have 10 to 20 times the mass of the Milky Way. The galaxy at lower right, 2MFGC 08638, is the most massive super spiral known to date, with a dark matter halo weighing at least 40 trillion Suns.

SALT OBSERVES SUPER FAST SPIRALS!

Astronomers using SALT have measured the rotation of some of the largest spiral galaxies, spinning at up to 570 kilometres per second! Their rapid spin is a result of sitting within an extraordinarily massive cloud, or halo, of dark matter – invisible matter detectable only through its gravitational influence. The largest "super spiral" studied here resides in a dark matter halo weighing at least 40 trillion times the mass of our Sun.

The Milky Way, an average spiral galaxy, spins at a speed of 210 kilometres per second in our Sun's neighbourhood. New research has found that the most massive spiral galaxies spin faster than expected. These "super spirals," the largest of which weigh about 20 times more than our Milky Way, spin at a rate of up to 570 kilometres per second.

Super spirals are exceptional in almost every way. In addition to being much more massive than the Milky Way, they're also brighter and larger in physical size. The largest span 450,000 light-years compared to the Milky Way's 100,000 light-year diameter. Only about 100 super spirals are known to date. Super spirals were discovered as an important new class of galaxies while studying data from the Sloan Digital Sky Survey as well as the NASA/IPAC Extragalactic Database (NED).

"Super spirals are extreme by many measures," says Patrick Ogle of the Space Telescope Science Institute in Baltimore, Maryland. "They break the records for rotation speeds."

Ogle is the first author of a paper that was published October 10, 2019, in the Astrophysical Journal Letters. The paper presents new data on the rotation rates of super spirals collected with SALT, the largest single optical telescope in the southern hemisphere. Additional data were obtained using the 5-meter Hale telescope of the Palomar Observatory, operated by the California Institute of Technology. Data from NASA's Wide-field Infrared Survey Explorer (WISE) mission was crucial for measuring the galaxy masses in stars and star formation rates.

"This work beautifully illustrates the powerful synergy between optical and infrared observations of galaxies, revealing stellar motions with SDSS and SALT spectroscopy, and other stellar properties — notably the stellar mass or 'backbone' of the host galaxies — through the WISE mid-infrared imaging," says Tom Jarrett of the University of Cape Town, South Africa.

Theory suggests that super spirals spin rapidly because they are located within incredibly large clouds, or halos, of dark matter. Dark matter has been linked to galaxy rotation for decades. Astronomer Vera Rubin pioneered work on galaxy rotation rates, showing that spiral galaxies rotate faster than if their gravity were solely due to the constituent stars and gas. An additional, invisible substance known as dark matter must influence galaxy rotation. A spiral galaxy of a given mass in stars is expected to rotate at a certain speed. Ogle's team finds that super spirals significantly exceed the expected rotation rate.

Super spirals also reside in larger than average dark matter halos. The most massive halo that Ogle measured contains enough dark matter to weigh at least 40 trillion times as much as our Sun. That amount of dark matter would normally contain a group of galaxies rather than a single galaxy.

"It appears that the spin of a galaxy is set by the mass of its dark matter halo," Ogle explains.

The fact that super spirals break the usual relationship between galaxy mass in stars and rotation rate is a new piece of evidence against an alternative theory of gravity known as Modified Newtonian Dynamics or MOND. MOND proposes that on the largest scales like galaxies and galaxy clusters, gravity is slightly stronger than would be predicted by Newton or Einstein. This would cause the outer regions of a spiral galaxy, for example, to spin faster than otherwise expected based on its mass in stars. MOND is designed to reproduce the standard relationship in spiral rotation rates, therefore it cannot explain outliers like super spirals. The super spiral observations suggest no non-Newtonian dynamics is required.

Despite being the most massive spiral galaxies in the universe, super spirals are actually underweight in stars compared to what would be expected for the amount of dark matter they contain. This suggests that the sheer amount of dark matter inhibits star formation. There are two possible causes: 1) Any additional gas that is pulled into the galaxy crashes together and heats up, preventing it from cooling down and forming stars, or 2) The fast spin of the galaxy makes it harder for gas clouds to collapse against the influence of centrifugal force.

"This is the first time we've found spiral galaxies that are as big as they can ever get," Ogle says.

Despite these disruptive influences, super spirals are still able to form stars. Although the largest elliptical galaxies formed all or most of their stars more than 10 billion years ago, super spirals are still forming stars today. They convert about 30 times the mass of the Sun into stars every year, which is normal for a galaxy of that size. By comparison, our Milky Way forms about one solar mass of stars per year.

Ogle and his team have proposed additional observations to help answer key questions about super spirals, including observations designed to study better the motion of gas and stars within their disks. After its 2021 launch, NASA's James Webb Space Telescope could study super spirals at greater distances and correspondingly younger ages to learn how they evolve over time. NASA's Nancy Grace Roman Space Telescope may help locate more super spirals, which are exceedingly rare, thanks to its large field of view.

Reference:
Ogle, P. M., et al 2019/10. Astrophys. J. Letters., 884. A Break in Spiral Galaxy Scaling Relations at the Upper Limit of Galaxy Mass.
https://doi.org/10.3847/2041-8213/ab459e

The Southern African Large Telescope (SALT), the largest optical telescope in the Southern Hemisphere Credit: SAAO (South African Astronomical Observatory).

MEERKAT AND SALT COMBINE TO SOLVE MYSTERY STELLAR EVENT

Scientists using the MeerKAT radio telescope and SALT have combined forces for the first time to discover and identify a unique and previously-unseen flare of radio emission from a binary star in our Galaxy.

The MeerKAT radio telescope in the Northern Cape of South Africa discovered the object which rapidly brightened by more than three times over a period of three weeks. This is the first new transient source discovered with MeerKAT and scientists hope it is just the tip of an iceberg of transient events to be discovered with the telescope in future.

Astronomers call an astronomical event "transient" when it lasts only for a short time, it may appear or disappear, or become fainter or brighter over seconds, days, or even years. These events are important as they provide a glimpse of how stars live, evolve, and die.

Using an assortment of telescopes around the globe, the researchers determined that the source of the flare is a binary system; where two objects orbit each other approximately every 22 days. While the cause of the flaring and the exact nature of the stars that make up the system is still uncertain, it is thought to be associated with an active corona – the hot outermost part of the brighter star.

The source of the observed activity is located in the Southern constellation of Ara and was found to be in the same place as a giant star about twice as massive as the Sun. The star's orbital motion was discovered and measured using optical observations with SALT. Fortuitously, the star is sufficiently bright to have also been monitored by optical telescopes for the last 18 years and is seen to vary in brightness every three weeks, matching the orbital period.

"This source was discovered just a couple of weeks after I joined the team, it was amazing that the first MeerKAT images I worked on had such an interesting source in them. Once we found out that the radio flares coincided with a star, we discovered that the star emits across almost the entire electromagnetic spectrum, from X-ray to UV to radio wavelengths," said Laura Driessen, a PhD student at The University of Manchester who led this work.

The discovery of this new transient with MeerKAT demonstrates how powerful this telescope will be in the search for further new transient events.

Patrick Woudt, Professor and Head of the Astronomy Department at The University of Cape Town said: "Since the inauguration in July 2018 of the South African MeerKAT radio telescope, the ThunderKAT project on MeerKAT has been monitoring parts of the southern skies to study the variable radio emission from known compact binary stars, such as accreting black holes.

"The excellent sensitivity and the wide field of view of the MeerKAT telescope, combined with the repeat ThunderKAT observations of various parts of the southern skies, allows us to search the skies for new celestial phenomena that exhibit variable or short-lived radio emission."

Dr David Buckley from the SAAO, who leads the SALT transient follow-up programme, which followed up on the discovery, commented: "This is a perfect example of where coordinated observations across different wavelengths were combined to give a holistic view of a newly discovered object.

"This study was one of the first to involve coordination between two of South Africa's major astronomy facilities and shows the way for future such work."

Professor Ben Stappers from The University of Manchester said: "The properties of this system don't easily fit into our current knowledge of binary or flaring stars and so may represent an entirely new source class."

The MeerKAT telescope is sweeping the sky for sources that vary on timescales from milliseconds to years, and will significantly improve human understanding of the variable radio sky. The discovery of this new transient with MeerKAT demonstrates how powerful this telescope will be in the search for further new transient events.

Rob Adam, Managing Director of the South African Radio Astronomy Observatory (SARAO) said: "Once again we see the potential of the MeerKAT telescope in finding interesting and possibly new astrophysical phenomena, as well as the power of the multi-wavelength approach to the analysis of observations."

Reference:
Driessen, L.N., et al 2019/10. MNRAS 491, 560: MKT J170456.2–482100: the first transient discovered by MeerKAT. https://doi.org/10.1093/mnras/stz3027

South Africa has already demonstrated its excellent science and engineering skills by designing and building the MeerKAT radio telescope – as a pathfinder to the SKA. The 64-antenna array is located at the SKA site at Losberg in the Karoo, about 90 kilometres from Carnarvon. Credit: SARAO (South African Radio Astronomy Observatory).

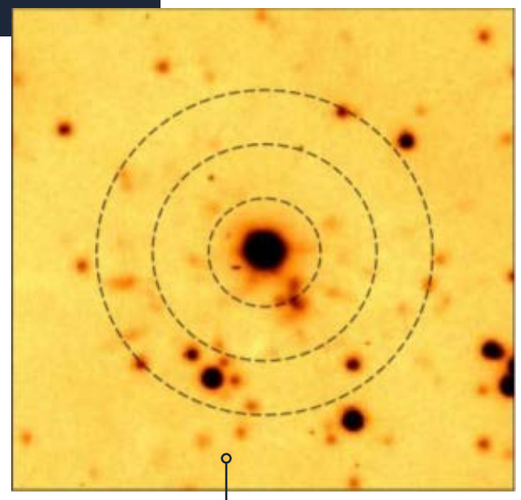
PLANETARY NEBULA WR 72 HAS HYDROGEN -POOR KNOTS, STUDY FINDS

Using SALT, astronomers have conducted spectroscopic and imaging observations of the planetary nebula WR 72. They discovered hydrogen-poor knots in the central part of the nebula, which could be helpful in improving knowledge about the nature of this object.

Planetary nebulae (PNe) are expanding shells of gas and dust that have been ejected from a star during the process of its evolution from a main-sequence star into a red giant or white dwarf. They are relatively rare but important for astronomers studying the chemical evolution of stars and galaxies. Of special interest are PNe exhibiting hydrogen poor material in their central regions. In some cases, the hydrogen-poor material appears as a fan of knots with cometary tails stretched radially from the central star. Detailed investigations of PNe of this type could shed more light on the process of low-mass star evolution.

Now, a team of astronomers led by Vasilii Gvaramadze of the Lomonosov Moscow State University, Russia, reports that the planetary nebula around WR 72, a Wolf–Rayet star of spectral type WO1 located some 4,630 light-years away, is the newest addition to the shortlist of PNe with hydrogen-poor knots. “We report the discovery of a handful of optical hydrogen-poor knots in the central part of an extended infrared nebula centered on the [WO1] star WR 72, obtained by spectroscopic and imaging observations with the Southern African Large Telescope,” the astronomers wrote in the paper.

The study, complemented by data from NASA’s Wide-field Infrared Survey Explorer (WISE), shows that the WR 72 nebula consists of an extended, nearly circular halo (about 7,800 light-years in diameter) and an elongated and apparently bipolar inner shell that contains the hydrogen-poor knots. The observations identified a bright knot to the southwest from WR 72 and a number of faint knots scattered around the star. The astronomers noted that some of the knots are elongated in the radial direction, as in the fan-like systems of hydrogen poor knots detected in the central regions of other PNe known as A 30 and A 78. The research found that the linear radius of the shell of WR 72 is around 0.75 light-years and the typical radial velocity of knots is 100 km/s.



SALT image of hydrogen-poor knots around WR72. Credit: Gvaramadze et al., 2019.

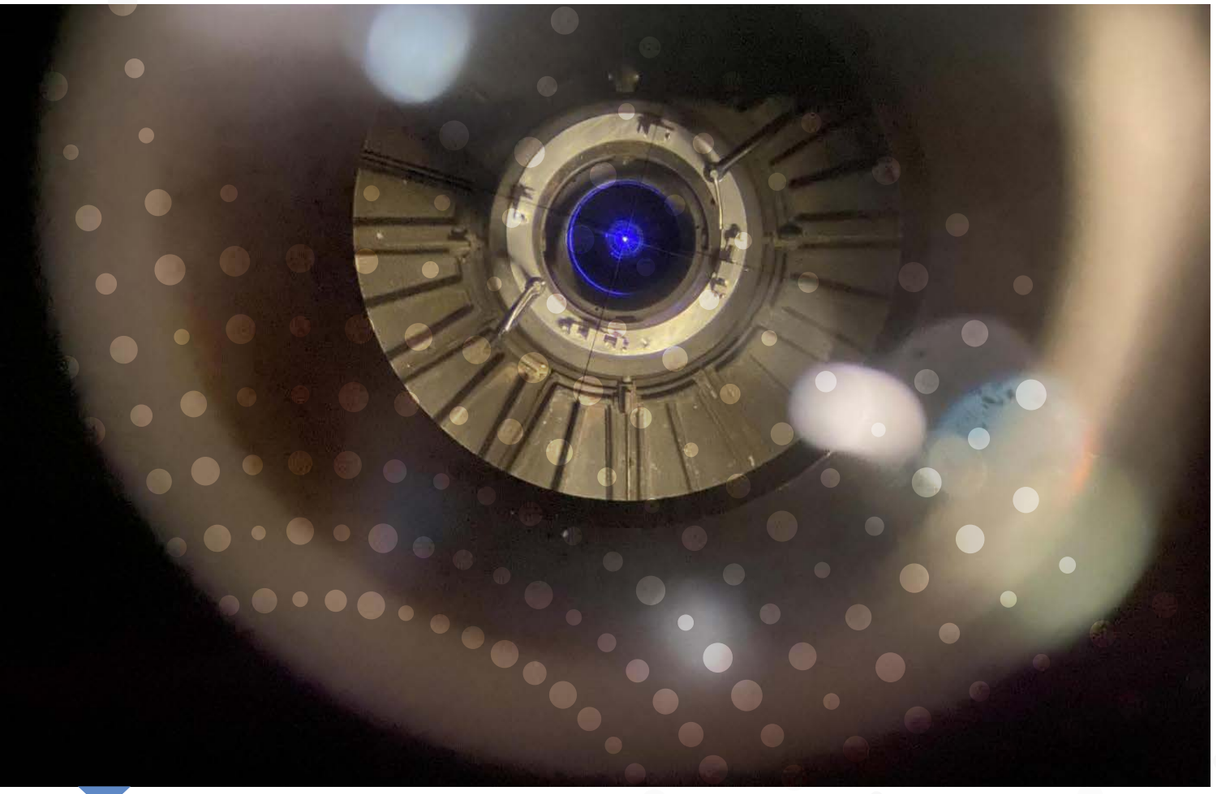
According to the scientists, these results suggest that the shell is about 1,000 years old. More studies of the knots are required, especially deeper and higher-resolution spectroscopy and imaging, in order to determine their abundances and to check whether their spatial distribution and kinematics are axially symmetric. The astronomers clarified that the detection of axial symmetry could mean that WR72 is a binary system. Summing up the results, the authors of the paper suggested the most plausible hypothesis that could explain the origin of WR 72. “Our findings indicate that WR72 is a new member of the rare group of hydrogen-poor planetary nebulae, which may be explained through a very late thermal pulse of a post-AGB star, or by a merger of two white dwarfs,” the astronomers concluded.

The astronomers noted that some of the knots are elongated in the radial direction, as in the fan-like systems of hydrogen poor knots detected in the central regions of other PNe known as A 30 and A 78.

Reference:
Gvaramadze, V.V., et al 2020/01. MNRAS 492, 3316. WR 72: a born-again planetary nebula with hydrogen-poor knots. WR 72: a born-again planetary nebula with hydrogen-poor knots. https://doi.org/10.1093/mnras/stz3639

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.

SAAO telescopes report

SAAO's observing station near Sutherland is home to many optical and infrared telescopes, ranging from the very large (SALT) to very small with a large field of view (KELT), to those having very large CCDs (e.g. KMTNet with its 18k x 18k CCD). 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 Lesedi, 1.9-m and 1.0-m telescopes is available on a competitive basis to astronomers world-wide, and all observing applications are vetted by a time allocation committee. Lesedi, and some of its instruments, is being commissioned, and observing time is available on a shared-risk basis to experienced observers. 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 traditionally given in blocks of weeks. This was as a result of logistical requirements relating 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. With the Covid-19 pandemic making it difficult to travel to Sutherland, it is now possible to operate all the SAAO telescopes (SALT, Lesedi, 1.9-m and 1.0-m telescopes) remotely from Cape Town, and therefore the need to allocate observing time in blocks of weeks is no longer a requirement on SAAO telescopes.

Subscription levels in the table below 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 the unallocated observing time after the deadline and applications for occultation observing time (which requires only a small fraction of a night).

Table:
Observing time subscription levels on the 1.9-m and 1.0-m telescopes for 2019.

Trimester (2019)	1.9-m(%)	1.0-m (%)
Trimester I (Jan - Apr)	129	94%
Trimester II (May – Aug)	122	100
Trimester III (Sep - Dec)	100	122
Average (2019)	117	105

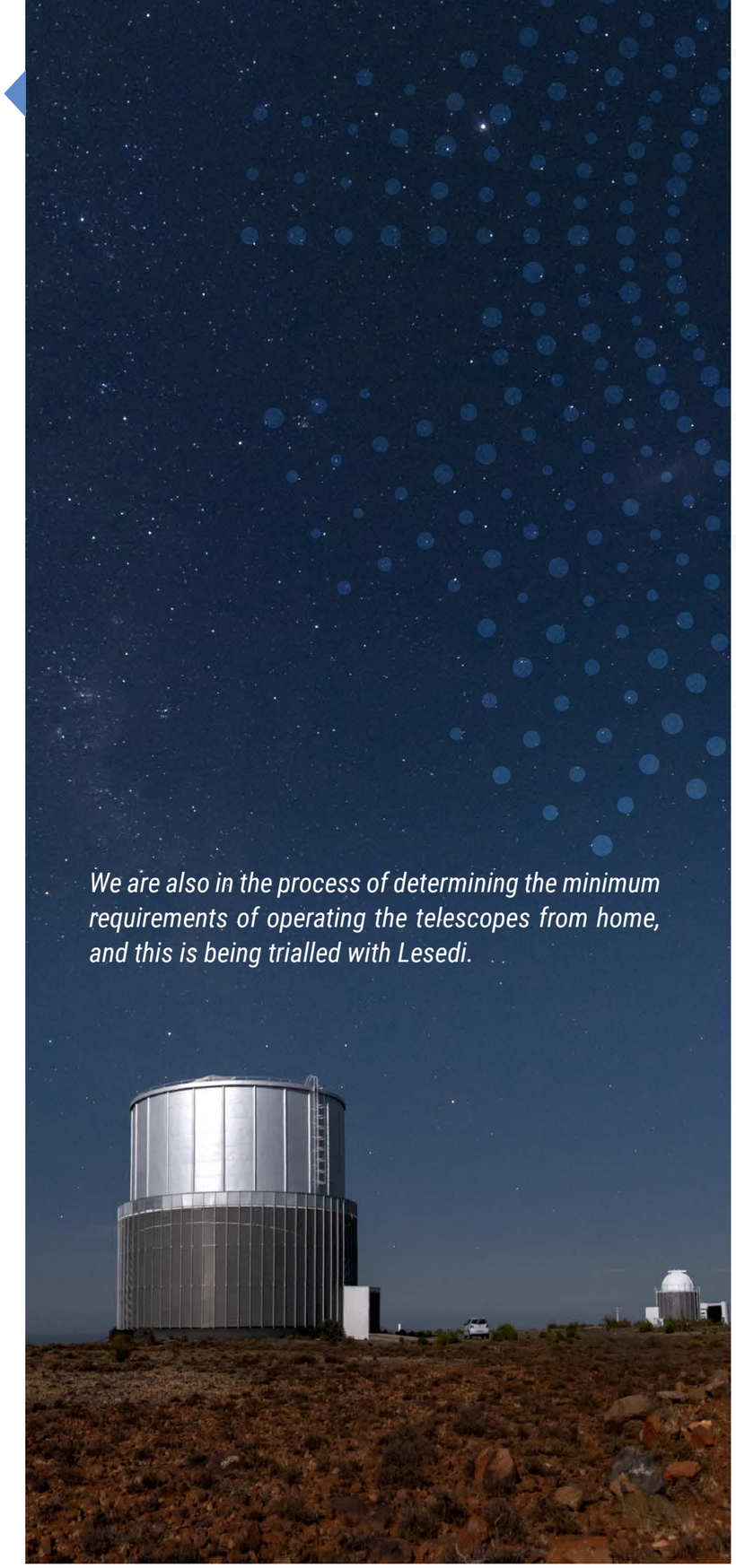
Subscription levels for Lesedi are not yet included in our subscription levels, given that the telescope is still mostly being commissioned, with the priority being on ensuring that everything is working within the specifications.

Remote observing

The three largest SAAO telescopes (1.9-m, 1.0-m and Lesedi) are now remotely operable from Cape Town with some of the instruments: The Sutherland High-Speed Optical Camera (SHOC; available on 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 are easily selectable without the need for an instrument change. The 1.0-m and 1.9-m telescopes have been equipped for remote observing, although instrument changes still require considerable manual effort and can only be done during the daytime. During the national lockdown, it was decided that we would have limited instrument changes on the telescopes, and that priority would be given to instruments that can be operated remotely. The priority, therefore, is to have SHOC on Lesedi and the 1.0m telescope, and SpUpNIC on the 1.9m telescope.

SHOC is frequently 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 involves the telescope being pointed into the software limits) and changing gratings and filters. The next priority is to reduce the number of manual operations on the 1.9m telescope when operating remotely. For example, we are exploring the possibility of putting the flat field screen on the telescope dome roof, within where the telescope can point without moving into the software limits. 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 rooms in Cape Town are in the East Wing of the Main Building, the SAAO Boardroom and the SALT Boardroom. The 1.0-m telescope is usually operated from the SAAO Boardroom, SALT from the SALT Boardroom and the 1.9-m telescope from the Main Building. We are also in the process of determining the minimum requirements of operating the telescopes from home, and this is being trialled with Lesedi. The requirements include internet speed, availability of computer monitors to display all the required telescope and instrument controls and the weather display.



AstroOps Summary

SALT is continuing on the publication trend expected for a telescope of its age and size, and 2019 broke the record on SALT refereed publications, with 54 publications in total (one of which is an instrument paper and not a science publication).

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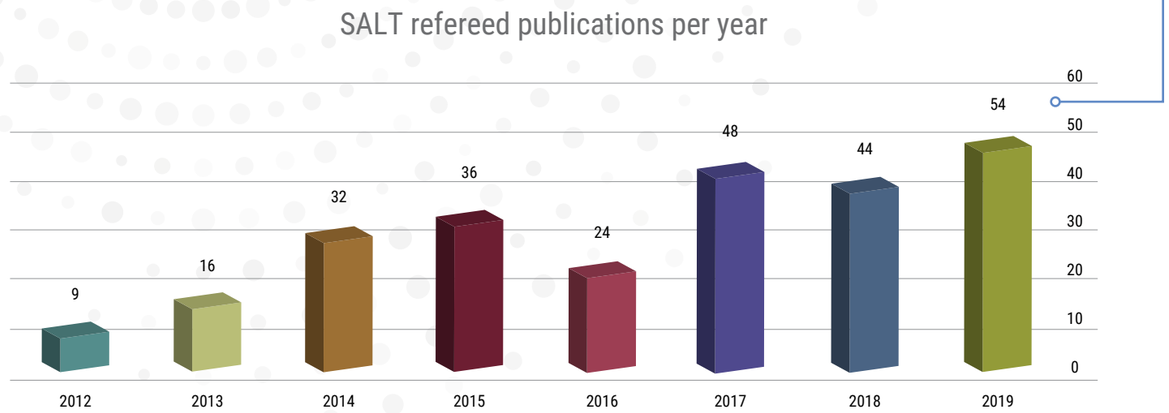
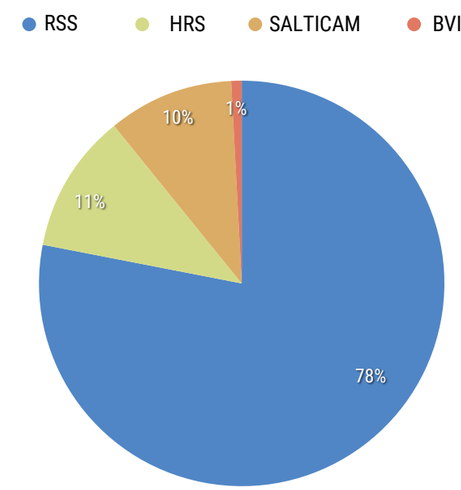
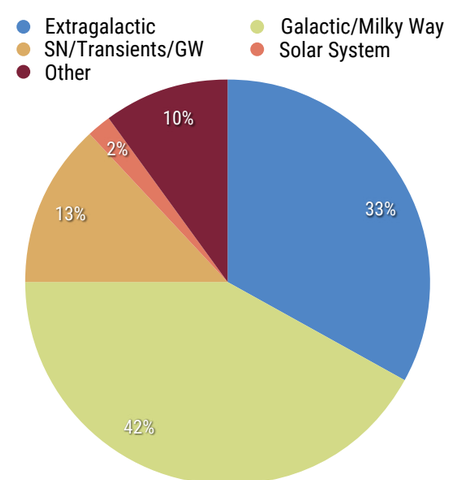


This brings us to nearly 300 papers since the beginning of SALT Operations in 2011. As can be seen from the pie charts, Galactic papers (especially stellar) dominate our publications, closely followed by our extragalactic community and with a strong component from our ToOs and transients.





The year 2019 has seen a large improvement in the time available for science, mainly as a result of slightly better weather conditions during the year.

Most of our papers to date come from RSS, which has traditionally been our main workhorse instrument, in particular its longslit mode. However, the picture has been changing over the last few years. While RSS remains our most popular instrument during our dark nights and best conditions, HRS is now our main workhorse instrument for worse weather/bright time, and its number of papers has also been on the increase.

It is also worth mentioning that, while SALTICAM and BVIT are not as popular for science due to them not having autoguiders, they are both incredibly efficient in terms of publication outputs.

Semester statistics

The year 2019 has seen a large improvement in the time available for science, mainly as a result of slightly better weather conditions during the year.

Our completion levels were comparable to those of previous years, improving from 71% in 2017-2 to nearly 80% in 2019-1 as the new RSS guider finally began to live up to its expectations and became the guider of choice by the SALT operators and astronomers. Unfortunately, a technical problem was discovered in August 2019 that affected all RSS linear spectropolarimetric observations taken during 2019, causing more technical downtime than expected. This fault was rectified in October and spectropolarimetric observations are now continuing successfully on SALT.

A significant effort was made during semester 2018-2 and 2019-1 to characterise the possibilities of the HRS high-stability mode, resulting in an increase in engineering time. The results of this are very encouraging: HRS is capable of 3m/s radial velocity precision when using the Iodine cell on very bright (<6th mag) stars, and 7-8m/s for fainter stars. Further investigation is currently on-going to establish the precision using the ThAr lamp and to explore the feasibility of procuring a Laser Frequency Comb.

User support

At the end of 2018, Astro-Ops launched a user support questionnaire to the SALT Astronomical community. The feedback from the community was overall very positive in terms of our support and planning tools, while very useful suggestions for improvement were also made and being addressed by the team, such as easier installation of the PySALT data reduction tools (this has now been achieved via Docker), updated documentation, a new SALT Data Archive which is nearly ready for deployment, and better support for the pipeline, for which we now have a dedicated SALT Astronomer.

The RSS Fabry-Pérot system went offline during 2019. The SALT Board approved the repairs of the MR and the LR etalons, together with support for this mode in the form of a 2-3 year SALT Postdoc with a dedicated focus on Fabry-Pérot science and support.

Personnel

Dr Enrico Kotze then joined the ranks as a SALT Astronomer in April 2019. His main focus is the SALT primary data reduction pipeline, which he has been re-developing in Python 3, making it more modular, incorporating some data quality checks and removing IRAF dependencies.

Dr Brent Miszalski's contract also expired at the end of December 2019. The process to fill this vacancy was initiated in October 2019 and Dr Lee Townsend was appointed as a SALT Astronomer in February 2020. Similarly, the SALT postdoc position with focus on Fabry-Pérot science and support was advertised in October 2019 - this position had not been filled by the end of the financial year.

We have also initiated a process of training SAAO's postdocs and allowing them to take observations using SALT. This is a win-win situation, where the postdocs get training on one of the largest telescopes in the world and gain better understanding of SALT, its capabilities and its instrumentation, while we also get a wider, more diverse team of observers. Dr Rajeev Manick, Dr Jessymol Thomas and Dr Solohery Randriamampandry have all received training in this manner during 2019, with Dr Manick having also had two observing weeks on his own.

In January 2019 we also welcomed Mr Sifiso Myeza's back to Astro-Ops, now as a full member of Dr Christian Hettlage's Astro-Ops software team. We also have a new NRF intern, Mr Lonwabo Zaula, also working with Christian's team for 2 years. Mr Zaula has also been heavily engaged in activities related to the Intelligent Observatory project of the SAAO.

Hosted facilities

SAAO not only provides research platforms for South African and international astronomers, but 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, currently do not pay facility fees (e.g., MeerLICHT and IRSF).

Some facilities give the South African astronomy community access to observing time. These include KMTNet, which allocates four blocks of 10 nights between October and February to SAAO usage, constituting about 10% of the total observing time; and the LCO, which 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 of the LCO telescopes in the world-wide network of equivalent telescopes at Sutherland (nine 1-m telescopes, and seven 0.4-m telescopes 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.

SAAO not only provides research platforms for South African and international astronomers, but it also hosts many national and international research facilities at Sutherland.

The ATLAS project is a collaboration between the University of Hawaii ATLAS Project and SAAO.

Future telescope projects

Three 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. The other telescope that SAAO is expecting in the near future is the Solaris-5, a 1.0m telescope similar to the two Solaris telescopes at Sutherland, owned by Nicolaus Copernicus Astronomical Centre (NCAC) of the Polish Academy of Sciences. The SAAO and NCAC signed an MoA for the construction and operation of Solaris-5 earlier in 2020.

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.

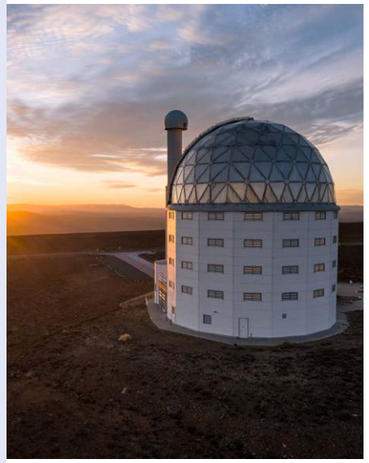
Interacting binaries – teams working on cataclysmic variables, symbiotic and X-ray binaries, identifying binaries in planetary nebulae.

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 11 am bring all these teams together. Non-SAAO researchers are also welcome.

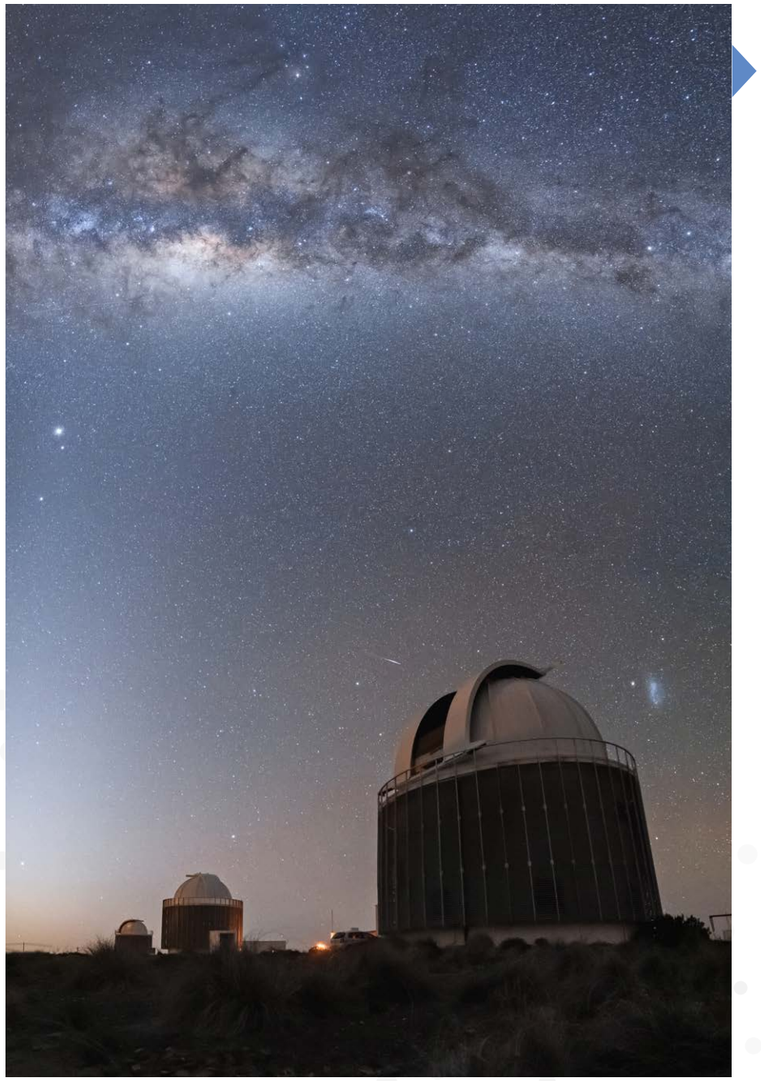


South Africa has had a long and rich history of stellar astronomy, for example, the first-ever measurement of the distance to a star (Alpha Centauri) was made here in 1833.

Planetary astronomy group

We have a small but active, professional planetary science research group at the SAAO. Our 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 rotational periods and colours of both near-Earth and main-belt asteroids through broadband photometry. There is also involvement in ground-based observations in support of ongoing and future planetary space missions (e.g New Horizons and DART).

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, former SAAO researcher Amanda Sickafoose has been involved in building such instruments. For example, the SHOC instrument, which is now available on the 1.0-m, 1.9-m and Lesedi telescopes, has been frequently used to observe stellar occultations by Pluto, Chiron, 55636, and other TNOs. The SHOC cameras have also been used for the light-curve observations of our near-Earth asteroid programme as relatively short exposure times are also essential because of the large sky-motion of these objects.



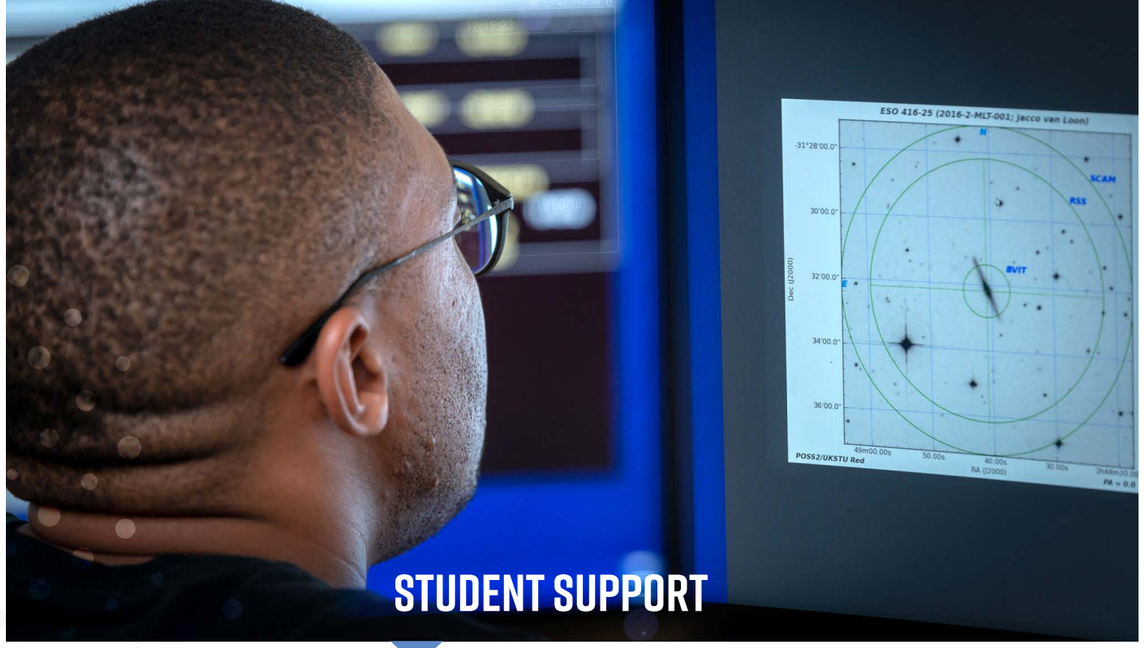
The topics of interest are mostly explored from an observational perspective, using optical, near-infrared and radio data from telescopes around the world, but there are also researchers simulating galaxy formation using high-performance computer clusters at SAAO and elsewhere.

Galaxy group

A number of staff and students at SAAO are working on extragalactic astronomy and galaxy evolution. The wide range of research interests explored includes star formation in galaxies, active galactic nuclei (AGN), feedback processes from supernovae and AGN, ultra-diffuse galaxies, the evolution of brightest cluster galaxies (BCGs) and mergers of galaxies. The group meets informally to discuss the latest research and share ideas and encourages emerging researchers to present their work and get feedback.

The topics of interest are mostly explored from an observational perspective, 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 to study very faint dwarf galaxies in nearby voids, star-forming rings around lenticular galaxies, kinematics and outflows from galaxies, galaxies in the MeerKAT LADUMA and MIGHTEE large science project fields, galaxies in clusters and black holes at the centres of galaxies.

An exciting new large science programme started on SALT in 2019 to measure the distances to BCGs and better understand their evolution. This collaboration between SALT partners in South Africa (led by Matt Hilton, UKZN), India and the USA, is using SALT to observe BCGs identified by the Advanced Atacama Cosmology Telescope (AdvACT) telescope out to very large distances. Complementary multi-wavelength data from SALT and the MeerKAT radio array will allow us to measure the 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. Approximately half of the sample has been observed to date and we look forward to the next phase of analysis.



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.

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

THE INTELLIGENT OBSERVATORY (IO) PROGRAMME

Design image of the remote observing station, showing the screen of the night sky above.

Credit: Jonathan Green/ Some Architects

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. The vision of the Sutherland Observatory is to eventually have all SAAO telescopes, in particular Lesedi, the 1.0-m, the 1.9-m and SALT tied into the AIO network. Multiple hosted facilities are also anticipated to contribute, e.g. by 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 is 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. For example, the 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.

During 2019 the AIO concept was envisaged resulting in a detailed Operational Concept Description (OCD) and a Program and Engineering Management Plan (PEMP) by the end of 2019. An initial core team of the PI, PM and 2 software developers were formed in early 2020.

Before the AIO can become a reality, the telescopes will have to be upgraded and adapted to become more autonomous. As of July 2020 developments on Lesedi, the 1.0-m and the 1.9-m are making this more possible. The COVID-19 pandemic has fast-tracked developments such that all three telescopes are now being operated remotely almost 100% of the time. Similarly SALT is now operated entirely remotely. Software developments have included the first release of a real-time systems monitoring dashboard and local control units (LCUs) for the 3 SAAO telescopes. The LCUs will replace many functions of an astronomer operating the telescope and instrument. This first release of the LCU has the ability to monitor the weather and force a shutdown of the telescopes if the weather goes outside of acceptable conditions. In mid 2020 a feasibility study was initiated to explore the possibility to upgrade the 1.9m telescope with a multi-instrument port.

During 2019 the AIO concept was envisaged resulting in a detailed Operational Concept Description (OCD) and a Program and Engineering Management Plan (PEMP) by the end of 2019.

Remote Command Center

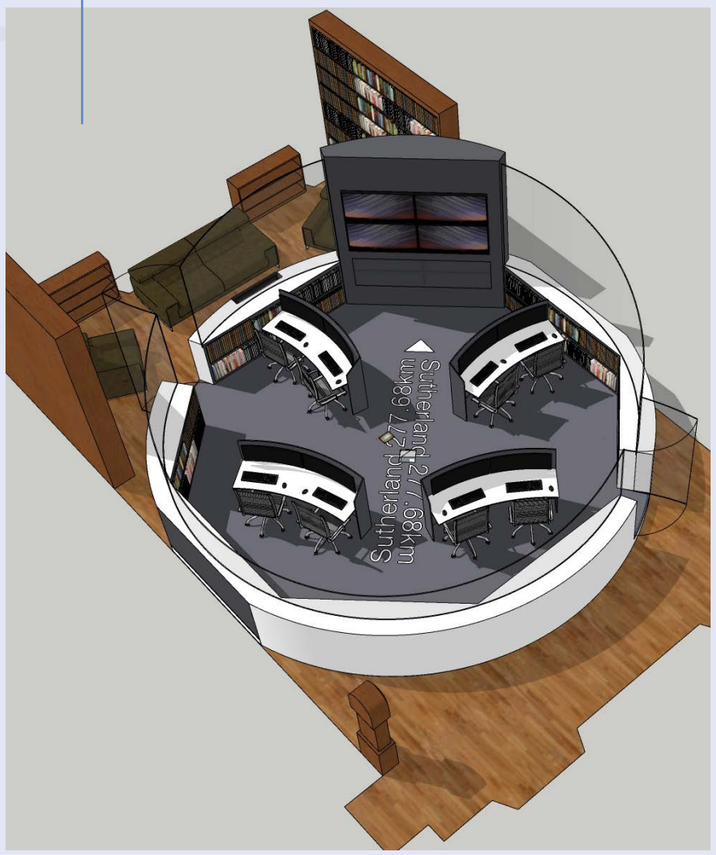
To support the AIO, a state-of-the-art control center is planned at the SAAO headquarters in Cape Town. It will be placed in one of the current library rooms, divided into a relaxation area and a circular platform for the observers with desks, computers and a bank of monitors.

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 sounds from the relevant telescope domes to ensure immediate feedback when any equipment is moved. The command center will be encased in glass walls so that dignitaries and the general public can experience real-live action of astronomers at work. In addition to being a remote control room for observers, it will also ultimately be the command center from which all the autonomous functions of the AIO will be managed and monitored.

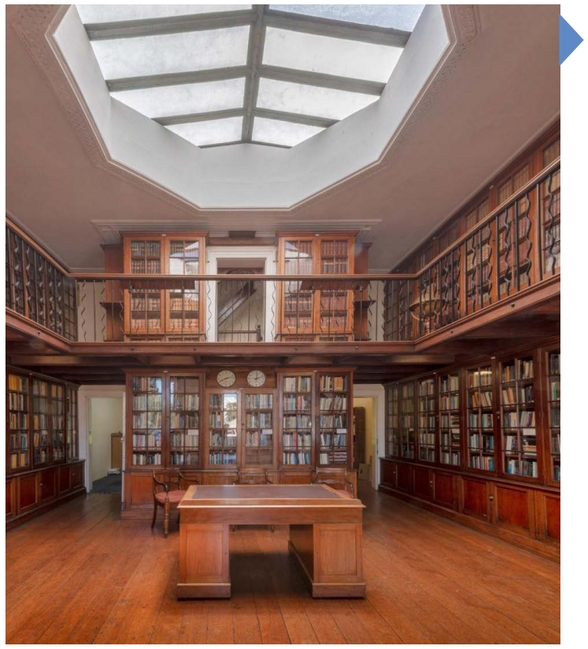
A separate room was repurposed to house the contents of the library room designated for the command center. The new library room underwent significant floor strengthening, basic re-decorating and a modern set of shelf compactors was installed. This was completed in early 2020.

View of the library room with the remote observing station and relaxation area behind.

Credit: Jonathan Green/Some Architects



SUPPORTING DEPARTMENTS



Library and Information services

In 2019, the refurbishment of the library saw the installation of compact mobile shelving to accommodate 37.8 metres of library material as phase 1 of the Remote Operations Room and Library Upgrade Project. Staff and students were provided with access to 844 e-books and 142 journals (both online and in print). Over 10 000 full-text articles were requested and downloaded from online journals by library users.

Furthermore, the library maintained a publications database and provided statistics for Key Performance Indicator (KPI) reporting on publications.

Information and Technology services

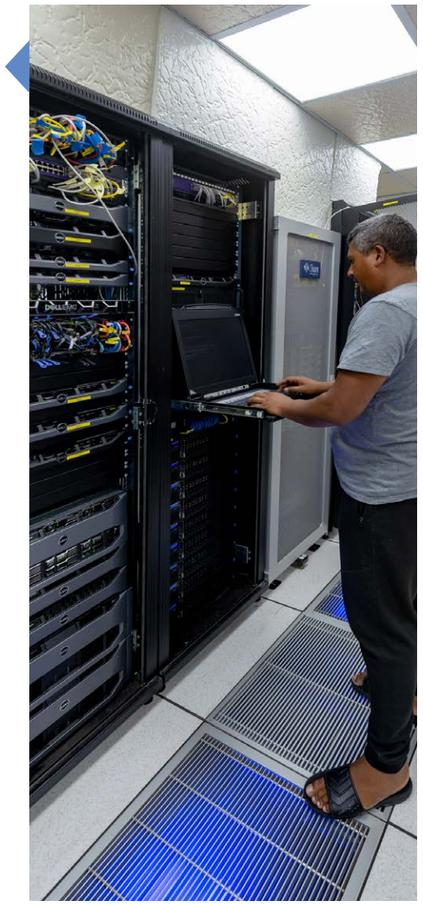
During 2019, the Information Technology Division faced quite a few difficulties with the SAAO infrastructure. Load-shedding placed a very high load on air conditioning equipment and Uninterruptible Power Supplies (UPS) batteries. For a period of a few weeks, the entire site was run on generator power and the IT department was on high alert for any potential failures. These unfortunate conditions made it essential that the environment was altered to make it more resilient. Systems were identified that required more regular maintenance and ways were found to automate certain functions.

Outside of the emergency mode, improvements were also made to the way services are delivered, such as the use of Docker for specialised software installations, the new SAAO website (www.saao.ac.za) and a few other sites and hosted services.

In Sutherland, there was an upgrade to service in the SALT cluster, as well as certain SALT servers. The SPS servers were deployed and the cabling was also completed during this period. Earlier in the year, SAAO hosted the IT forum with all the major players within the NRF facilities, which included SARAO, SAEON, iThemba LABS and SAIAB. The main item of discussion was the new ERP (Enterprise Resource Planning) system that is now deployed NRF wide.

Other items of interest over the past year include the upgrade of the networking in House 4, the 1896 Building's video conferencing system, and the relocation and upgrade of the SALT boardroom. The installation of the Max-E office and the optical lab network was also done during this time.

The onset of the COVID-19 pandemic necessitated equipping staff to work effectively from home. Changes to the VPN service were made to improve performance and allow more users to access the network from remote locations and IT has made Zoom the SAAO video conferencing system of choice.



OUTREACH AND EDUCATION

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 people by, for example, hosting school groups, offering visitors a tour of the telescopes at 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 and fun for science enthusiasts. Our aim is creating a more 'astronomy-aware' audience across the country and beyond. Furthermore, SAAO hosts numerous educational resources on its website, aimed at educating learners. For the youngest children (grade R) we have 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-building workshops, star gazing nights, site tours, and day and night tours at Sutherland. The snapshots show some of the visits we had from schools in the reporting period.

St Agnes Primary School, 23rd April 2019

Applewood Preparatory, 2nd May 2019

Ambleside School of Hout Bay, 7th May 2019

Soneike High School, 12th June 2019

Edgemead High, 23rd July 2019

Blouberg Ridge Primary, 5th to 7th August 2019

Abeille Ruche, 14th August 2019

Pacaltsdorp Primary School, 3rd September 2019

Oranjemund Private School, 4th September 2019

Welgemoed Primary, 10th & 11th September 2019

Star of the Sea Convent School, 16th October 2019

St Cyprian's Primary School, 26th & 27th November 2019

EDUCATOR WORKSHOPS

As part of our outreach, SAAO provides workshops for teachers. These focus on scientific subject matter, 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 consist of presentations about "matter and material", astronomy, and telescopes and binoculars. The curriculum workshops are particularly aimed at advising teachers on how to assist learners with science concepts and models.

Walacedene High – Teacher Workshop, 12th October 2019

Walacedene High – Teacher Workshop, 12th October 2019

Limpopo Teacher Workshops, 2nd to 6th September 2019

KZN Teacher Workshops, 8th to 12th April 2019

PSP Teacher Workshop at Ravensmead High School, 5th October 2019

REACHING THE PUBLIC

SAAO's Open Nights are held twice a month on a Saturday and include a public lecture, a stargazing session and a visit to the SAAO museum. The lectures are mostly given by South African astronomers, but occasionally a visitor from overseas talks about 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 Centre and offers tours of selected telescopes.

The majority of the public are engaged via 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 relate to South Africa's two world-class telescopes: SALT and the MeerKAT radio telescope array.

OUTREACH HIGHLIGHTS

International Observe the moon night.

On 5th October 2019, Nazir Makda and Christian Hettlage teamed up with members of the Astronomical Society of Southern Africa's Cape Centre for a joint event at the V&A Waterfront in Cape Town.

This was part of the international "Observe the Moon Night", and hundreds of members of the public got a chance to look at our Earth's natural satellite through one of the telescopes.

Members of the public also had an opportunity to view the Sun and, once it was sufficiently dark, marvel at Jupiter with all four Galilean Moons, or Saturn with its beautiful rings. Children also got a chance to simulate craters by throwing sweets into a bowl of flour. Many children went home with a certificate to prove that they indeed observed the Moon!

Astronomy Quiz

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

A total of 498 learners from the Western Cape and 320 learners from Northern Cape participated in the 2019 national quiz. The provincial winners of the Western Cape, namely Park Laerskool Mossel Bay were crowned 2019 National Winners in the finals held in Johannesburg, where they competed with the winners from the other 8 provinces. The annual Astronomy Quiz for Grade 7 learners remains very popular in both the Western and Northern Cape. The use of the online version of the Quiz has made it easier for rural-based learners and schools to participate.

Due to the success of the quiz, the Western Cape Education Department has made participation compulsory for all primary schools in the Western Cape. The greatest challenge remains the fact that many primary schools use Afrikaans as a medium of instruction and the quiz is currently only offered in English. SCBP, with the help of Mr Willie Koorts and the support of SAASTA, have begun the process of translating the Astro Quiz booklet into Afrikaans, which will encourage participation for learners in the Northern Cape and Free State where Afrikaans is used as the language of instruction.

Teachers look forward to participating in the quiz as it not only improves the knowledge content, confidence of the learners and their interest in science, but it also provides teachers with resources and exposure to modern discoveries and current updates.

Park Primary, 1st place.

Mohammedeya Primary, 2nd place.

St Andrews Primary, 5th place.

Rondebosch East Primary, 4th place.

Outeniqua Primary, 3rd place

National Science Week

South Africa dedicates the first week of August of every year to celebrating the achievements of science and technology.

The week is used to try to inspire learners and students to decide on science-based studies, as well as 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 29th July 2019 to 4th August 2019, SAAO staff held workshops concurrently in the Northern Cape and the Western Cape. In the Northern Cape, Sutherland's SCBP staff: Jeremy Stuurman, Pranesthan Govender, Delshia Kamfer and Francois Klein, visited schools, arranging talks and presenting workshops all over the Northern Cape – all in an effort to raise awareness about science. In the Western Cape, Cedric Jacobs visited the West Coast to host Astronomy workshops. Over 2000 learners were reached in these events.

Astronomy and space science are usually the main themes - which gives SAAO the opportunity to be more involved in the activities whilst promoting astronomy.

Snapshots of National Science Week

Job shadowing

Two job shadowing sessions were held during the June and September school vacations.

A total of 28 learners (13 learners in the first two-day session held on 2nd and 3rd of July; and 15 learners in the second one held on the 25th and 26th of September) drawn from various high schools participated in the programme. This involved astronomers, software developers, information technology staff, engineers, education and outreach personnel. Our job shadowing programme has been transformed from one focused on astronomy exclusively, to a holistic programme that also highlights related careers and the roles they play in astronomy as a field. It is a two-day intensive programme that takes learners through experiences of observers and theorists. It takes them through a continuum of observation, data collection, analysis and interpretation. They are supplied with practical information on the various institutions of higher learning that offer relevant courses, details of where and when to apply for bursaries and scholarships, and last but not least, an opportunity to observe and ask questions of the various practitioners.

Job Shadow group 2 – 25th & 26th September 2019

Job Shadow group 1– 2nd & 3rd July 2019

Video link: https://www.youtube.com/watch?v=wpG4R_geeJU

SAAO advancing indigenous knowledge creatively and innovatively

Southern African peoples have deep and profound relationships with the heavens and stars.

In ancient times, they used stars in connection with calendars and agriculture as well as to regulate their ceremonies and for navigation. The SAAO has also promoted indigenous astronomy knowledge through lectures, posters and workshops.

Recently we have produced a short video, which seeks to communicate and re-affirm the significance of indigenous astronomy, while raising awareness about the advances made by South Africa in the field of modern astrophysics. The video is part of an NRF-SAAO led Indigenous Astronomy Project which is sponsored by the Department of Science and Innovation. As part of this project we have completed the "The Stars under Karoo Skies: Science Communicators workshop on Storytelling" and have included indigenous knowledge as part of teacher training workshops. A DVD will be created with a compilation of all the work done in indigenous astronomy in Southern Africa, including articles, books, videos, posters, artworks, astronomy software and will also have the full record of all interviews conducted as part of the production of the video.

Following this work, Sivuyile Manxoyi was invited by the North American Association of Science and Technology Centre (ASTC) to present advances made in recognising and presenting indigenous astronomy knowledge, in Toronto, Canada. He was also part of a panel with colleagues from Australia, Brazil and the US.

The SALT Collateral Benefits Programme and the SAAO relationship with the town of Sutherland are leading initiatives related to interacting with communities living near observatories and setting an example for others to follow. Indigenous astronomy knowledge serves to highlight the multicultural roots of astronomy and shows that all peoples of the world have a relationship with the universe.

Career Exhibitions and Expos

In an effort to disseminate information about astronomy as a career, share the pathway, provide details of institutions that offer astronomy courses and distribute information about astronomy opportunities and facilities, the SALT Collateral Benefits Programmer has participated in career exhibitions and expos.

Working jointly with SARAO, a career exhibition was held in Villiersdorp in the Northern Cape and was attended by 269 learners. A mini career expo was also held in Touws River and it attracted 180 learners. SCBP also participated in the Eastern Cape-based Careers Expo which was held in the Buffalo City Metro and Umtata municipality. 1079 Grade 11 and 12 learners attended the careers expo in Mthatha; 417 learners attended the Jongilizwe and 735 learners attended the St Johns Career Expo. SCBP staff also joined in at the UCT Eskom Career Expo and managed to interact and engage with 150 learners.

These careers expos provide us with an opportunity to share information on astronomy as a discipline as well as a career; they also offer us opportunities to popularise SALT, the work of SAAO and Astronomy in South Africa and in the world in general.

Building on this annual project, we intend to encourage continuous and on-going interactions with selected girls in Cape Town and Sutherland.

Women's Day Event

The annual Women's Day event was held on the 9th of August 2019, a day celebrated nationally as Women's Day.

A total of 60 girl learners drawn from various schools across the Western Cape were addressed by different female science and technology professionals. Astronomy, software development and space physics were among the careers represented in the event. The learners had opportunities to interact with the female scientists in an informal and relaxed setting, where they were able to ask all the questions they had. The learners were given packs containing various brochures and books based on different careers.

Building on this annual project, we intend to encourage continuous and on-going interactions with selected girls in Cape Town and Sutherland. It is important for girl learners to have an online (via email or social media) science mentor or role model to continue the conversation and sustain the interest raised during the Women's Day celebrations.

STAFF HIGHLIGHTS

The Launch of The Cosmic Savannah Podcast

An exciting new podcast about African astronomy was launched in March 2019.

The podcast, called The Cosmic Savannah, showcases the discoveries, research topics, people, technology and various initiatives involved in the world of professional astronomy across the African continent. The aim of the podcast is to engage the African and international general public in African astronomy and space science. No prior knowledge of astronomy is needed to enjoy the podcast.

The Cosmic Savannah is the initiative of Dr Jacinta Delhaize from the University of Cape Town and Dr Daniel Cunnama from the SAAO. Dr Delhaize and Dr Cunnama are both professional astronomers based in Cape Town and are passionate about communicating astronomy with the public. Each episode, Dr Cunnama and Dr Delhaize chat to different members of the astronomy community from across the African continent. Africa's beautiful dark skies and vast plains make it an ideal place to conduct world-class cutting-edge astronomy research.

The first three episodes of The Cosmic Savannah were released on 29th March 2019 and the occasion was marked with a launch party held at the SAAO. These episodes discuss topics such as near-Earth asteroids, the Breakthrough Listen project to search for extraterrestrial intelligence using South Africa's MeerKAT, and what it's like to observe with SALT - the largest optical telescope in the Southern Hemisphere. New episodes are released fortnightly.

You can find out more about The Cosmic Savannah at www.thecosmicsavannah.com and on Twitter and Facebook @cosmicsavannah. You can subscribe to The Cosmic Savannah wherever you get your podcasts, including iTunes, Spotify, Google Podcasts, Stitcher, Soundcloud, Pocketcasts, etc.

The first three episodes of The Cosmic Savannah were released on 29th March 2019 and the occasion was marked with a launch party held at the South African Astronomical Observatory.

Ian Glass 80th Birthday

An initiative by SAAO Librarian, Theresa de Young, saw Dr Ian Glass receive a surprise 80th birthday party in the SAAO Library on Friday, 6th September 2019.

Ian, a retired SAAO Astronomer, who celebrated his birthday the day before, was kept completely in the dark and looked quite overwhelmed by the surprise and turnout. Many of his fellow retirees, such as Greg Roberts, Isobel Bassett and Ethleen Lastovica, were present to celebrate and make the day even more memorable for him. Ian's wonderful wife, Hettie, was in on the surprise and had been sending in pictures on the sly which, together with contributions from Willie Koorts, Chantal Fourie and Auke Slotegraaf (Chair at the Centre for Astronomical Heritage and a close friend of Ian's) were used to make a slideshow. The slide show was pieced together by Willie and displayed in the background throughout the morning, and it was later presented to Ian.

Long after his retirement, Ian Glass has continued to offer his support, guidance and assistance in various aspects of SAAO, including the Museum, Archive and the Library. Throwing this special surprise party for Ian was just a very small token of appreciation for all that he has done, and for all he continues to do at the SAAO. Patricia Whitelock delivered a speech focusing on Ian's many accomplishments, one of which was that he is the author of a number of books on SAAO History. Ian responded by sharing a few highlights of his long, illustrious career.

Throwing this special surprise party for Ian was just a very small token of appreciation for all that he has done, and for all he continues to do at the SAAO.

Itumeleng Monageng's invitation to the Lindau Nobel Laureate meeting

On 4th March 2019, the Academy of Science of South Africa (ASSAf) announced that one of our young 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-doctoral 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 scientists 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.

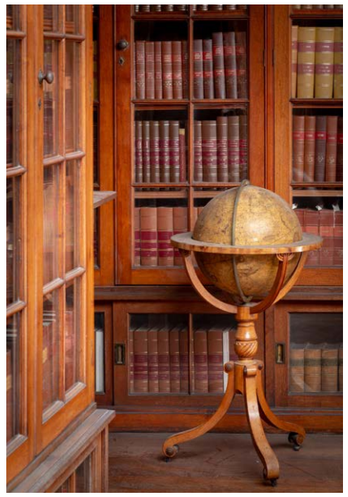
Ekse Profiles South African Astronomical Observatory

In August 2019, local television station Cape Town TV visited the SAAO to film a show for Ekse, a magazine programme aimed at local youth.

As part of the show's "SciTech Wednesday" series, Ekse's dynamic young presenter Llama Lee Moon visited the McClean telescope and the mechanical workshop, where Daniel Cunnama and Malcolm Hendriks highlighted some of the technological developments at the observatory from the late 19th century to today.

The show included a studio interview with astronomers Rosalind Skelton and Itumeleng Monageng, who discussed topics ranging from careers in astronomy and opportunities in South Africa, to SALT, to what we mean by multiwavelength astronomy and whether there are aliens out there!

SAAO STUDENTS



SAAO STUDENTS

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

During 2019, 13 SAAO staff members supervised or co-supervised 11 MSc and 12 PhD students registered at various South African universities (the majority at UCT). Eighteen of these 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.

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

GRADUATED STUDENTS

Abubakr Yagob, MSc, UCT

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

Abstract:
I present an analysis of the dispersion measure (DM) variations for 68 pulsars. The observations were taken using six International LOFAR Stations in Europe over the period of 3.5 years (between June 2014 and November 2017) at the centre frequency of 150 MHz with 80 MHz of bandwidth. During this time each pulsar was observed on a weekly basis, resulting in an average of 160 observations per source. I show that the variations of the DM measurements show various trends along the span of the observation: increasing or decreasing, and in some cases more changes from one trend to another. I perform the structure function analysis for each of the pulsars included in the study, in order to check if the DM variations follow the Kolmogorov power spectrum which describes the turbulence structure of the interstellar medium (ISM). I find that for a number of pulsars' results show consistency with the Kolmogorov distribution (e.g. PSRs J1913-0440and J2157+4017), while other sources show significant difference (e.g. PSRs J0108+6608and J0614+2229). I also obtain the DM derivatives (i.e. dDM/dt) for each pulsar, in order to examine the correlation between the DM and its derivative. The result of this correlation shows a best-fit with a gradient of 0.6±0.2, which is comparable with the result that was previously obtained by Hobbs et al. (2004), who shows a dependence of square-root between the DM and its derivative; with a gradient of 0.57(9). Also, one of the major results of this study that, thanks to the timing analysis, allowed me to produce a new timing solution for three pulsars: PSRs J0613+3731, J0815+4611 and J1740+27. This study concludes in that: i) the DM variations can be used to understand the general properties of the ISM, ii) the low-frequency observations can enable us to study the dispersion effect on pulsar signals, which can be very useful for the effort of the pulsar timing array (PTA) project, iii) ISM studies using pulsar timing is a powerful technique requiring a careful approach to data reduction and analysis due to characteristics of the pulsars.

Curtly Blows, MSc, UCT

Title:
Reinforcement Learning for Telescope Optimisation.
Supervisor:
Bruce Bassett (SAAO)

Abstract:
Reinforcement learning is a relatively new and unexplored branch of machine learning with a wide variety of applications. This study investigates reinforcement learning and provides an overview of its application to a variety of different problems. We then explore the possible use of reinforcement learning for telescope target selection and scheduling in astronomy, with the hope of effectively mimicking the choices made by professional astronomers. This is relevant as next-generation astronomy surveys will require near real-time decision making in response to high-speed transient discoveries. We experiment with and apply some of the leading approaches in reinforcement learning to simplified models of the target selection problem. We find that the methods used in this study show promise but do not generalise well. Hence while there are indications that reinforcement learning algorithms could work, more sophisticated algorithms and simulations are needed.

Emmanuel Dufourq, PhD, UCT

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

Abstract:
The primary objective of this thesis is to investigate whether evolutionary concepts can improve the performance, speed and convenience of algorithms in various active areas of machine learning research. Deep neural networks are exhibiting an explosion in the number of parameters that need to be trained, as well as the number of permutations of possible network architectures and hyper-parameters. There is little guidance on how to choose these and brute-force experimentation is prohibitively time consuming. We show that evolutionary algorithms can help tame this explosion of freedom, by developing an algorithm that robustly evolves near optimal deep neural network architectures and hyper-parameters across a wide range of image and sentiment classification problems. We further develop an algorithm that automatically determines whether a given data science problem is of classification or regression type, successfully choosing the correct problem type with more than 95% accuracy. Together these algorithms show that a great deal of the current "art" in the design of deep learning networks - and in the job of the data scientist - can be automated. Having discussed the general problem of optimising deep learning networks the thesis moves on to a specific application: the automated extraction of human sentiment from text and images of human faces. Our results reveal that our approach is able to outperform several public and/or commercial text sentiment analysis algorithms using an evolutionary algorithm that learned to encode and extend sentiment lexicons. A second analysis looked at using evolutionary algorithms to estimate text sentiment while simultaneously compressing text data. An extensive analysis of twelve sentiment datasets reveal that accurate compression is possible with 3.3% loss in classification accuracy even with 75% compression of text size, which is useful in environments where data volumes are a problem. Finally, the thesis presents improvements to automated sentiment analysis of human faces to identify emotion, an area where there has been a tremendous amount of progress using convolutional neural networks. We provide a comprehensive critique of past work, highlight recommendations and list some open, unanswered questions in facial expression recognition using convolutional neural networks. One serious challenge when implementing such networks for facial expression recognition is the large number of trainable parameters which results in long training times. We propose a novel method based on evolutionary algorithms, to reduce the number of trainable parameters whilst simultaneously retaining classification performance, and in some cases achieving superior performance. We are robustly able to reduce the number of parameters on average by 95% with no loss in classification accuracy. Overall our analyses show that evolutionary algorithms are a valuable addition to machine learning in the deep learning era: automating, compressing and/or improving results significantly, depending on the desired goal.

Kimeel Sooknunan, MSc, UCT

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

Abstract:
With the advent of powerful telescopes such as the Square Kilometre Array (SKA), its precursor MeerKAT and the Large Synoptic Survey Telescope (LSST), we are entering a golden era of multiwavelength transient astronomy. The large MeerKAT science project ThunderKAT may dramatically increase the detected number of radio transients. Currently radio transient datasets are still very small, allowing spectroscopic classification of all objects of interest. As the event rate increases, follow-up resources must be prioritised by making use of early classification of the radio data. Machine learning algorithms have proven themselves invaluable in the context of optical astronomy, however it has yet to be applied to radio transients. In the burgeoning era of multi-messenger astronomy, incorporating data from different telescopes such as MeerLICHT, Fermi, LSST and the gravitational wave observatory LIGO could significantly improve classification of events.

Here we present MALT (Machine Learning for Transients): a general machine learning pipeline for multiwavelength transient classification. In order to make use of most machine learning algorithms, “features” must be extracted from complex and often high-dimensional datasets. In our approach, we first interpolate the data onto a uniform grid using Gaussian processes, we then perform a wavelet decomposition and finally reduce the dimensionality using principal component analysis. We then classify the light curves with the popular machine learning algorithm random forests. For the first time, we apply machine learning to the classification of radio transients. Unfortunately, publicly available radio transient data is scarce and our dataset consists of just 87 light curves, with several classes only consisting of a single example. However machine learning is often applied to such small datasets by making use of data augmentation. We develop a novel data augmentation technique based on Gaussian processes, able to generate new data statistically consistent with the original. As the dataset is currently small, three studies were done on the effect of the training set. The classifier was trained on a non-representative training set, achieving an overall accuracy of 77.8% over all 11 classes with the known 87 lightcurves with just eight hours of observations. The expected increase in performance, as more training data are acquired, is shown by training the classifier on a simulated representative training set, achieving an average accuracy of 95.8% across all 11 classes. Finally, the effectiveness of including multiwavelength data for general transient classification is demonstrated. First the classifier is trained on wavelet features and a contextual feature, achieving an average accuracy of 72.9%. The classifier was then trained on wavelet features and a contextual feature, together with a single optical flux feature. This addition improves the overall accuracy to 94.7%. This work provides a general approach for multiwavelength transient classification and shows that machine learning can be highly effective at classifying the influx of radio transients anticipated with MeerKAT and other radio telescopes.

Melaku Sisay Tafere, MSc, UCT

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

Abstract:
Abstract In this MSc thesis, I investigated the kinematics of Hα emission from the hot ionised and NaD absorption from cool neutral gas in a sample of 40 nearby Luminous Infrared Galaxies (LIRGs: LIR ≥ 1011L) from Supernovae and starbursts in the infrared, SUNBIRD survey imaged with the Southern African Large Telescope (SALT). This project can be seen in two major areas. The first is analysing the emission and absorption spectra, in this case from the hot ionised gas and cool gas respectively. Two routines were used for the profile fitting, to get the centroid wavelength of both the emission and absorption lines; Gaussian and Gaussian-Hermite functions were used. The fitting result provides an indication of the origin of an outflowing gas; nuclear or disk driven. Secondly, I plotted and compared the velocities of hot ionised and cool neutral gas. Three different methods were used to estimate the systemic velocity (V sys) for the accurate estimation of outflowing velocity. For instance, an outflowing NaD up to 380 kms−1 and inflowing gas up to -100 kms−1 relative to Hα is seen at the optical nucleus of the NGC6240 [PA=45] and NGC1204 [PA=253] galaxies respectively. I tested if there was a relation between star formation rate (SFR) and an outflowing gas and also whether the inflowing gas triggers new nuclear SF. I find the gas of two of our targets escaping the potential well of the host galaxy. There was also an expectation that the out flowing velocity would correlate with SFR, unfortunately I do not see any correlation, though it needs further investigation of all offset velocities of the gas with respect to stellar absorption lines and it also requires detailed analysis of the of projection or orientation effect on the galaxy.

Nazir Makda, MSc UCT

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

Abstract:
The evolution of galaxies in the cluster environment is a complex process, with many outstanding questions. A wide range of galaxy morphologies, colours, sizes and luminosities are found in clusters, the least studied of which are the faint galaxy populations. Studying the faint end of the galaxy luminosity distribution may provide a valuable insight into the evolution of galaxies in cluster environments. The Largest of these faint galaxies are classified as Ultra-Diffuse galaxies (UDGs). UDGs are low surface brightness galaxies with a very low stellar mass component, however they have sizes comparable to the Milky Way. These galaxies are hard to detect and classify as they are very faint. To survive in the cluster environments, where they have been observed, these galaxies must contain significant amounts of dark matter as the strong tidal fields would normally tear diffuse low-mass galaxies apart. The high abundance of UDGs in clusters has only recently been recognised, therefore identifying and measuring their properties is key to understanding how they are formed and continue to exist. In this thesis, I search for low surface brightness galaxies, spanning from typical dwarf galaxies to UDGs, in 16 low redshift (z<0.15) clusters in the deep IAC Stripe 82 Legacy project data by selecting cluster members based on color-magnitude cuts and modelling their two-dimensional light distributions to obtain sizes and surface brightness values. This is the largest sample of clusters in which anyone has searched for UDGs before in a uniform way. A total of 941 galaxies are identified in the 16 Stripe 82 clusters with surface brightness μe(g)<= 24 mag/arcsec2 and effective radius ~ 1.5 kpc; an average of 59 per cluster. Of these, 165 are classified as UDGs following van Dokkum et al. (2015). The larger and fainter galaxies are easily distinguished above non-cluster background distributions. Find that the surface brightness profiles are typically exponential, n~1, implying disk morphologies and the axis ratios are evenly spread, <b/a>= 0.52. The number of faint galaxies in clusters follows a power-law with respect to the cluster halo mass, N∝M1.05±0.45, determined through bootstrap resampling. This shows that the number of UDG candidates increases as the cluster halo mass increases.

STUDENT PROFILES

PHD STUDENTS

Anja Genade | UCT
Title: Observational studies of centaur characteristics
Supervisors: Amanda Sickafoose (SAAO), Paul Groot

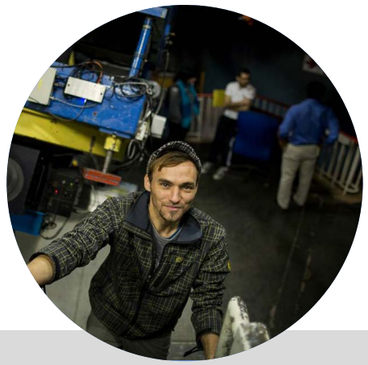
Antoine Mahoro | UCT
Title: Outflows from star-forming galaxies and AGN
Supervisors: Petri Väisänen (SAAO), Kurt van der Heyden (UCT)

Bynish Paul | UJ
Title: 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
Title: Frontiers in machine learning and Bayesian statistics in science
Supervisors: Bruce Bassett (AIMS/UCT/SAAO)

Etsegenet Alemu | UCT
Title: Luminous Infrared Variables in Nearby Galaxies
Supervisors: Patricia Whitelock (SAAO/UCT)

Gerald Nathan Balekaki | UCT
Title: 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)



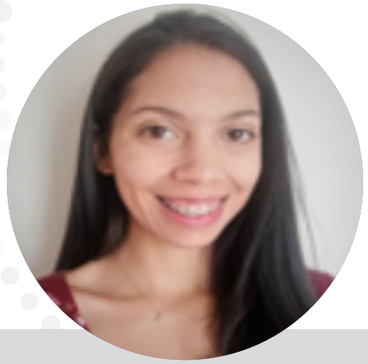
Hannes Breytenbach | UCT
Title: Magnetic cataclysmic variables
Supervisors: David Buckley (SAAO), Patrick Woudt (UCT)

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

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

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

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

Naomi van Jaarsveld | UCT
Title: Multi-wavelength study of neutron stars in the Magellanic Clouds
Supervisors: Vanessa McBride (SAAO/OAD/UCT), David Buckley (SAAO)

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

MSC STUDENTS

Anke van Wyk | UCT
Title: Determining the underlying abundances of different transient and variable star populations
Supervisors: Vanessa McBride (SAAO) and Paul Groot

Danté Hewitt | UCT
Title: Studying 8 nearby novalike systems that have been observed by MeerKAT as part of the ThunderKAT project
Supervisors: Dr Retha Pretorius (SAAO) and Prof Patrick Woudt (UCT)

Geoff Murphy | UCT
Title: Modelling how stellar halos form and enrich the Universe
Supervisors: Rob Yates, Daniel Cunnama (SAAO), Shazrene Mohamed (SAAO/UCT)

Kelebogile Bonokwane | UCT
Title: SALT HRS Radial Velocity Monitoring of Central Stars of Planetary Nebulae
Supervisors: Brent Miszalski (SAAO), Shazrene Mohamed (SAAO/UCT)

Munira Hoosain | UCT
Title: Measuring galaxy environments in the LADUMA field
Supervisors: Rosalind Skelton (SAAO), Dr Sarah Blyth (UCT)

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

Omphemetse Mputle | UCT
Title: The WiFeS Ionized Gas Kinematics of a sample of MHONGOOSE Galaxies
Supervisors: Moses Mogotsi (SAAO), Matthew Bershady.

Orapeleng Mogawana | UCT
Title: Simulating massive exploding stars and making model predictions of their radio emission
Supervisors: Shazrene Mohamed (SAAO/UCT)

Petronella van Rensburg | UCT
Title: Characterising small (<300m in diameter), close-approaching near-Earth asteroids
Supervisors: Nicolas Erasmus (SAAO), Matthew Bershady (SAAO)

Phumlani Sangweni | UCT
Title: Design and development of the SAAO building structures at the Observatory site in Cape Town: Based on ergonomics design and accessibility, water control and structural balance
Supervisors: Matthew Bershady (SAAO)

HONOURS STUDENTS

- **Andrew Firth (UCT),** supervised by Matt Bershady (SAAO)
- **Kabelo Malapane (UCT),** supervised by Shazrene Mohammed (SAAO)
- **Katlego Ramalatswa (UCT),** supervised by Shazrene Mohammed (SAAO)
- **Jaco Brink (UCT),** supervised by David Buckley (SAAO)
- **Malema Ranonyai (UCT),** supervised by Retha Pretorius (SAAO)
- **Noko Monyebodi (UCT),** supervised by Rosalind Skelton (SAAO)
- **Wanga Mulaudzi (UCT),** supervised by Matt Bershady (SAAO)

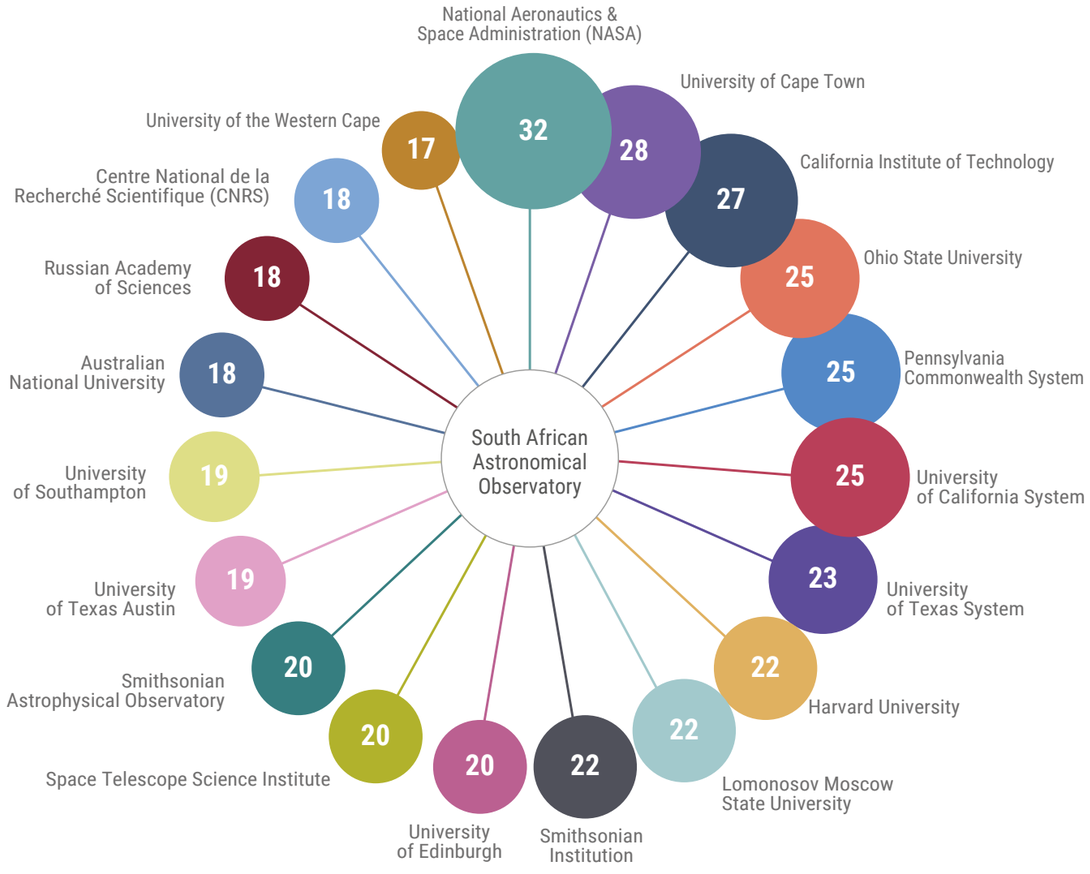
SAAO PERFORMANCE

PUBLICATIONS

Refereed publications by SAAO staff:	136 (36 of which use SAAO & hosted facilities)
Refereed publications by non-SAAO staff based on SAAO & hosted facilities:	126
Total refereed publications:	**262**

Breakdown of refereed publications using SAAO & hosted facilities based on 162 publications

SALT	53
LCOGT	25
KMTNet	22
SuperWASP (de-commissioned)	19
MASTER	18
IRSF	16
1.0-m	8
BiSON	7
1.9-m	7
ATLAS	1
MONET	1



COLLABORATIONS

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.

Organisations SAAO has most frequently collaborated with, based on 136 publications

Name	Web of Science Documents
National Aeronautics & Space Administration (NASA)	32
University of Cape Town	29
California Institute of Technology	27
Ohio State University	25
Pennsylvania Commonwealth System of Higher Education (PCSHE)	25
University of California System	25
Lomonosov Moscow State University	24
University of Texas System	23
Harvard University	22
Smithsonian Institution	22
Russian Academy of Sciences	20
Smithsonian Astrophysical Observatory	20
Space Telescope Science Institute	20
University of Edinburgh	20
Soutern African Large Telescope (FDN)	19
University of Southampton	19
University of Texas Austin	19
Australian National University	18
Centre National de la Recherche Scientifique (CNRS)	18
Max Planck Society	17
University of the Western Cape	17
Istituto Nazionale Astrofisica	16
NASA Goddard Space Flight Center	15
University of St Andrews	15
Massachusetts Institute of Technology (MIT)	14
University of Copenhagen	14
University of Warsaw	14
Pennsylvania State University	14
University of Warwick	14
Instituto de Astrofisica de Canarias	14
Pennsylvania State University - University Park	14
European Southern Observatory	14

Organisations that have published on SAAO & hosted facilities, based on 162 publications

South African Astronomical Observatory (SAAO), South Africa:	42
Center for Astrophysics (CfA), USA:	39
Max Planck Society (MPG), Germany:	38
University of Warwick (U Warwick), UK:	35
Ohio State University (OSU), USA:	35
California Institute of Technology (CalTech), USA:	35
Goddard Space Flight Center:	27
University of Warsaw (UW), Poland:	22
Korea NST, Korea:	22
Spanish Research Council (CSIC), Spain:	20
Chinese Academy of Sciences (CAS), Beijing:	18
Tsinghua University (Tsinghua U), China:	18
University of Cambridge (U Camb), UK:	17
University of Tokyo (U Tokyo), Japan:	19
Keele University (Keele U), UK:	16

Staff

Total number: **176**

By department:

	Total	Male	Female	CT Based	Sutherland Based
Science	41	26	15	36	5
Technical/engineering	37	33	4	23	9
IT/Software support	12	11	1	10	2
Support (various)	42	17	25	25	17
Outreach	11	7	4	5	6
Students	27	17	10	--	--
Interns	6	3	3	6	

Students supervised by SAAO staff

Total:	**30**
Honours:	7
MSc:	11
PhD:	12
Students graduated in 2019:	5 (5 MSc)

Outreach

	Events	Attendees
Learners	152	25849
Educators	19	707
Public	58	15978

APPENDIX

PUBLICATION LISTS

Refereed Publications*
Publications with SAAO affiliation

Abbott, T. M. C., Alarcon, A., Allam, S., et al.: “Cosmological Constraints from Multiple Probes in the Dark Energy Survey”, 2019, Physical Review Letters, 122, 171301.

Abbott, T. M. C., Allam, S., Andersen, P., et al.: “First Cosmology Results using Type Ia Supernovae from the Dark Energy Survey: Constraints on Cosmological Parameters”, 2019, Astrophysical Journal Letters, 872, L30.

Aguado, D. S., Ahumada, R., Almeida, A., et al.: “The Fifteenth Data Release of the Sloan Digital Sky Surveys: First Release of MaNGA-derived Quantities, Data Visualization Tools, and Stellar Library”, 2019, Astrophysical Journals, 240, 23.

Arentsen, A., Starkenburg, E., Shetrone, M. D., et al.: “Binarity among CEMP-no stars: an indication of multiple formation pathways?”, 2019, Astronomy and Astrophysics, 621, A108.

Bachelet, E., Bozza, V., Han, C., et al.: “First Assessment of the Binary Lens OGLE-2015-BLG-0232”, 2019, Astrophysical Journal, 870, 11.

Balona, L. A.: “Evidence for spots on hot stars suggests major revision of stellar physics”, 2019, Monthly Notices of the RAS, 490, 2112.

Balona, L. A., Handler, G., Chowdhury, S., et al.: “Rotational modulation in TESS B stars”, 2019, Monthly Notices of the RAS, 485, 3457.

Becker, J. C., Vanderburg, A., Rodriguez, J. E., et al.: “A Discrete Set of Possible Transit Ephemerides for Two Long-period Gas Giants Orbiting HIP 41378”, 2019, Astronomical Journal, 157, 19.

Belfiore, F., Westfall, K. B., Schaefer, A., et al.: “The Data Analysis Pipeline for the SDSS-IV MaNGA IFU Galaxy Survey: Emission-line Modeling”, 2019, Astronomical Journal, 158, 160.

Berdnikov, L. N., Kniazev, A. Y., Dambis, A. K., et al.: “CCD Observations and Period Change of the Type ab RR Lyrae Star DV Mon”, 2019, Astrophysical Bulletin, 74, 183.

Berdnikov, L. N., Kniazev, A. Y., Kovtyukh, V. V., et al.: “Search for Evolutionary Changes in the Periods of Cepheids: BG Cru”, 2019, Astronomy Letters, 45, 445.

Berdnikov, L. N., Pastukhova, E. N., Kovtyukh, V. V., et al.: “Search for Evolutionary Changes in the Periods of Cepheids: V1033 Cyg, a Classical Cepheid at the First Crossing of the Instability Strip”, 2019, Astronomy Letters, 45, 227.

Bok, J., Blyth, S.-L., Gilbank, D. G., & Elson, E. C.: “Enhanced H I profile asymmetries in close galaxy pairs”, 2019, Monthly Notices of the RAS, 484, 582.
Bowman, D. M., & Holdsworth, D. L.: “VizieR Online Data Catalog: TEA-Phot python code (Bowman+, 2019)”, 2019, VizieR Online Data Catalog, J/A+A/629/A21.

Breytenbach, H., Buckley, D. A. H., Hakala, P., et al.: “Discovery, observations, and modelling of a new eclipsing polar: MASTER OT J061451.70-272535.5”, 2019, Monthly Notices of the RAS, 484, 3831.

Broussard, A., Gawiser, E., Iyer, K., et al.: “Star Formation Stochasticity Measured from the Distribution of Burst Indicators”, 2019, Astrophysical Journal, 873, 74.

Brout, D., Sako, M., Scolnic, D., et al.: “First Cosmology Results Using Type Ia Supernovae from the Dark Energy Survey: Photometric Pipeline and Light-curve Data Release”, 2019, Astrophysical Journal, 874, 106.

Brout, D., Scolnic, D., Kessler, R., et al.: “First Cosmology Results Using SNe Ia from the Dark Energy Survey: Analysis, Systematic Uncertainties, and Validation”, 2019, Astrophysical Journal, 874, 150.

Buckley, D. A. H.: “The changing landscape of South African astronomy”, 2019, Nature Astronomy, 3, 369.

Carnall, A. C., McLure, R. J., Dunlop, J. S., et al.: “The VANDELS survey: the star-formation histories of massive quiescent galaxies at 1.0 < z < 1.3”, 2019, Monthly Notices of the RAS, 490, 417.

Cembranos, J. A. R., de la Cruz-Dombriz, Á., Dunsby, P. K. S., & Méndez-Isla, M.: “Analysis of branon dark matter and extra-dimensional models with AMS-02”, 2019, Physics Letters B, 790, 345.

Charles, P., Matthews, J. H., Buckley, D. A. H., et al.: “Hot, dense He II outflows during the 2017 outburst of the X-ray transient Swift J1357.2-0933”, 2019, Monthly Notices of the RAS, 489, L47.

Charpinet, S., Brassard, P., Fontaine, G., et al.: “TESS first look at evolved compact pulsators. Discovery and asteroseismic probing of the g-mode hot B subdwarf pulsator EC 21494-7018”, 2019, Astronomy and Astrophysics, 632, A90.

Corbet, R. H. D., Chomiuk, L., Coe, M. J., et al.: “Discovery of the Galactic High-mass Gamma-Ray Binary 4FGL J1405.1-6119”, 2019, Astrophysical Journal, 884, 93.

Coughlin, M. W., Ahumada, T., Anand, S., et al.: “GROWTH on S190425z: Searching Thousands of Square Degrees to Identify an Optical or Infrared Counterpart to a Binary Neutron Star Merger with the Zwicky Transient Facility and Palomar Gattini-IR”, 2019, Astrophysical Journal Letters, 885, L19.

Crause, L. A., Gilbank, D., Gend, C. van ., et al.: “SpUpNIC (Spectrograph Upgrade: Newly Improved Cassegrain): a versatile and efficient low- to medium-resolution, long-slit spectrograph on the South African Astronomical Observatory’s 1.9-m telescope”, 2019, Journal of Astronomical Telescopes, Instruments, and Systems, 5, 024007.

Crawford, S. M.: “Reducing Optical Observations With Python”, 2019, Astronomical Data Analysis Software and Systems XXVI, 521, 503.

Cullen, F., McLure, R. J., Dunlop, J. S., et al.: “The VANDELS survey: the stellar metallicities of star-forming galaxies at 2.5 < z < 5.0”, 2019, Monthly Notices of the RAS, 487, 2038.

Cunha, M. S., Antoci, V., Holdsworth, D. L., et al.: “Rotation and pulsation in Ap stars: first light results from TESS sectors 1 and 2”, 2019, Monthly Notices of the RAS, 487, 3523.

Davé, R., Anglés-Alcázar, D., Narayanan, D., et al.: “SIMBA: Cosmological simulations with black hole growth and feedback”, 2019, Monthly Notices of the RAS, 486, 2827.

Dawson, R. I., Huang, C. X., Lissauer, J. J., et al.: “TOI-216b and TOI-216 c: Two Warm, Large Exoplanets in or Slightly Wide of the 2:1 Orbital Resonance”, 2019, Astronomical Journal, 158, 65.

Dominik, M., Bachelet, E., Bozza, V., et al.: “OGLE-2014-BLG-1186: gravitational microlensing providing evidence for a planet orbiting the foreground star or for a close binary source?”, 2019, Monthly Notices of the RAS, 484, 5608.

Dragomir, D., Teske, J., Günther, M. N., et al.: “TESS Delivers Its First Earth-sized Planet and a Warm Sub-Neptune”, 2019, Astrophysical Journal Letters, 875, L7.

Erasmus, N., McNeill, A., Mommert, M., et al.: “A Taxonomic Study of Asteroid Families from KMTNET-SAAO Multiband Photometry”, 2019, Astrophysical Journals, 242, 15.

Escorza, A., Karinkuzhi, D., Jorissen, A., et al.: “Barium and related stars, and their white-dwarf companions. II. Main-sequence and subgiant starss”, 2019, Astronomy and Astrophysics, 626, A128.

Estrada-Carpenter, V., Papovich, C., Momcheva, I., et al.: “CLEAR. I. Ages and Metallicities of Quiescent Galaxies at 1.0 < z < 1.8 Derived from Deep Hubble Space Telescope Grism Data”, 2019, Astrophysical Journal, 870, 133.

Feast, M. W., Griffin, R. F., Herbig, G. H., & Whitelock, P. A.: “R Coronae Borealis: radial velocity and other observations, 1950-2007”, 2019, Monthly Notices of the RAS, 482, 4174.

Fragkou, V., Parker, Q. A., Zijlstra, A. A., Crause, L., & Barker, H.: “A high-mass planetary nebula in a Galactic open cluster”, 2019, Nature Astronomy, 3, 851.

Garcia, B., Diaz-Merced, W., Casado, J., & Cancio, A.: “Evolving from xSonify: a new digital platform for sonorization”, 2019, European Physical Journal Web of Conferences, 200, 01013.

Gasque, L. C., Hening, C. A., Hviding, R. E., et al.: “Two Long-period Cataclysmic Variable Stars: ASASSN-14ho and V1062 Cyg”, 2019, Astronomical Journal, 158, 156.

Geballe, T. R., Banerjee, D. P. K., Evans, A., et al.: “Infrared Spectroscopy of the Recent Outburst in V1047 Cen (Nova Centauri 2005)”, 2019, Astrophysical Journal Letters, 886, L14.

Goldman, S. R., Boyer, M. L., McQuinn, K. B. W., et al.: “An Infrared Census of DUST in Nearby Galaxies with Spitzer (DUSTiNGS). V. The Period-Luminosity Relation for Dusty Metal-poor AGB Stars”, 2019, Astrophysical Journal, 877, 49.

Gomel, R., Shahaf, S., Mazeh, T., et al.: “SB 796: a high-velocity RRc star”, 2019, Monthly Notices of the RAS, 482, 5327.

Green, P. J., Montez, R., Mazzoni, F., et al.: “A Chandra Study: Are Dwarf Carbon Stars Spun Up and Rejuvenated by Mass Transfer?”, 2019, Astrophysical Journal, 881, 49.

Gromadzki, M., Hamanowicz, A., Wyrzykowski, L., et al.: “Discovery and follow-up of the unusual nuclear transient OGLE17aaj”, 2019, Astronomy and Astrophysics, 622, L2.

Groot, P. J.: “The multi-colour dynamic Universe explored”, 2019, Nature Astronomy, 3, 1160.

Gvaramadze, V. V., Pakhomov, Y. V., Kniazev, A. Y., et al.: “TYC 8606-2025-1: a mild barium star surrounded by the ejecta of a very late thermal pulse”, 2019, Monthly Notices of the RAS, 489, 5136.

Gvaramadze, V. V., Kniazev, A. Y., & Oskinova, L. M.: "Discovery of a putative supernova remnant around the long-period X-ray pulsar SXP 1323 in the Small Magellanic Cloud", 2019, Monthly Notices of the RAS, 485, L6.

Gvaramadze, V. V., Maryeva, O. V., Kniazev, A. Y., et al.: "CPD-64°2731: a massive spun-up and rejuvenated high-velocity runaway star", 2019, Monthly Notices of the RAS, 482, 4408.

Gvaramadze, V. V., Kniazev, A. Y., Castro, N., & Grebel, E. K.: "Two Circumstellar Nebulae Discovered with the Wide-field Infrared Survey Explore and Their Massive Central Stars", 2019, Astronomical Journal, 157, 53.

Gvaramadze, V. V., Gräfener, G., Langer, N., et al.: "A massive white-dwarf merger product before final collapse", 2019, New Astronomy, 569, 684.

Günther, M. N., Pozuelos, F. J., Dittmann, J. A., et al.: "A super-Earth and two sub-Neptunes transiting the nearby and quiet M dwarf TOI-270", 2019, Nature Astronomy, 3, 1099.

Hahn, C., Starkenburg, T. K., Choi, E., et al.: "IQ-Collaboratory 1.1: The Star-forming Sequence of Simulated Central Galaxies", 2019, Astrophysical Journal, 872, 160.

Hakala, P., Ramsay, G., Potter, S. B., et al.: "TESS observations of the asynchronous polar CD Ind: mapping the changing accretion geometry", 2019, Monthly Notices of the RAS, 486, 2549.

Hill, A. R., van der Wel, A., Franx, M., et al.: "High-redshift Massive Quiescent Galaxies Are as Flat as Star-forming Galaxies: The Flattening of Galaxies and the Correlation with Structural Properties in CANDELS/3D-HST", 2019, Astrophysical Journal, 871, 76.

Huang, C., Zou, H., Kong, X., et al.: "The Mass□Metallicity Relation at z □ 0.8: Redshift Evolution and Parameter Dependency", 2019, Astrophysical Journal, 886, 31.

Huang, S., Katz, N., Davé, R., et al.: "The robustness of cosmological hydrodynamic simulation predictions to changes in numerics and cooling physics", 2019, Monthly Notices of the RAS, 484, 2021.

Iłkiewicz, K., Mikołajewska, J., Miszalski, B., et al.: "LMC S154: the first Magellanic symbiotic recurrent nova", 2019, Astronomy and Astrophysics, 624, A133.

Jeffery, C. S., & Miszalski, B.: "EC 22536-5304: SALT identifies a new lead-rich intermediate helium subdwarf", 2019, Monthly Notices of the RAS, 489, 1481.

Johns, D., Reed, P. A., Rodriguez, J. E., et al.: "KELT-23Ab: A Hot Jupiter Transiting a Near-solar Twin Close to the TESS and JWST Continuous Viewing Zones", 2019, Astronomical Journal, 158, 78.

Jones, D., Boffin, H. M. J., Sowicka, P., et al.: "The short orbital period binary star at the heart of the planetary nebula M 3-1", 2019, Monthly Notices of the RAS, 482, L75.

Joyce, M., Lairmore, L., Price, D. J., Mohamed, S., & Reichardt, T.: "Density Conversion between 1D and 3D Stellar Models with ^{1D}MESA2HYDRO^{3D}", 2019, Astrophysical Journal, 882, 63.

Karambelkar, V. R., Adams, S. M., Whitelock, P. A., et al.: "SPIRITS Catalog of Infrared Variables: Identification of Extremely Luminous Long Period Variables", 2019, Astrophysical Journal, 877, 110.

Katkov, I. Y., Kniazev, A. Y., Kasparova, A. V., & Sil'chenko, O. K.: "The imprint of the thick stellar disc in the midplane of three early-type edge-on galaxies in the Fornax cluster", 2019, Monthly Notices of the RAS, 483, 2413.

Kessler, R., Brout, D., D'Andrea, C. B., et al.: "First cosmology results using Type Ia supernova from the Dark Energy Survey: simulations to correct supernova distance biases", 2019, Monthly Notices of the RAS, 485, 1171.

Khangale, Z. N., Potter, S. B., Kotze, E. J., Woudt, P. A., & Breytenbach, H.: "High-speed photometry of the eclipsing polar UZ Fornacis", 2019, Astronomy and Astrophysics, 621, A31.

Kilkenny, D., Worters, H. L., & Lynas-Gray, A. E.: "New hot subdwarf variables from the EC survey", 2019, Monthly Notices of the RAS, 485, 4330.

Kniazev, A. Y., Usenko, I. A., Kovtyukh, V. V., & Berdnikov, L. N.: "The MAGIC Project. I. High-Resolution Spectroscopy on Salt Telescope and the Cepheid RsNor as a Test Object", 2019, Astrophysical Bulletin, 74, 208.

Kostov, V. B., Schlieder, J. E., Barclay, T., et al.: "The L 98-59 System: Three Transiting, Terrestrial-size Planets Orbiting a Nearby M Dwarf", 2019, Astronomical Journal, 158, 32.

Kovtyukh, V., Lemasle, B., Kniazev, A., et al.: "The MAGIC project - II. Discovery of two new Galactic lithium-rich Cepheids", 2019, Monthly Notices of the RAS, 488, 3211.

Labadie-Bartz, J., Rodriguez, J. E., Stassun, K. G., et al.: "KELT-22Ab: A Massive, Short-Period Hot Jupiter Transiting a Near-solar Twin", 2019, Astrophysical Journals, 240, 13.

Lagrange, A.-M., Meunier, N., Rubini, P., et al.: "Evidence for an additional planet in the β Pictoris system", 2019, Nature Astronomy, 3, 1135.

Laskar, T., van Eerten, H., Schady, P., et al.: "A Reverse Shock in GRB 181201A", 2019, Astrophysical Journal, 884, 121.

Lasker, J., Kessler, R., Scolnic, D., et al.: "First cosmology results using Type IA supernovae from the dark energy survey: effects of chromatic corrections to supernova photometry on measurements of cosmological parameters", 2019, Monthly Notices of the RAS, 485, 5329.

Leja, J., Johnson, B. D., Conroy, C., et al.: "An Older, More Quiescent Universe from Panchromatic SED Fitting of the 3D-HST Survey", 2019, Astrophysical Journal, 877, 140.

Li, Q., Narayanan, D., & Davé, R.: "The dust-to-gas and dust-to-metal ratio in galaxies from z = 0 to 6", 2019, Monthly Notices of the RAS, 490, 1425.

Lipunov, V. M., Gorbovskoy, E., Kuznetsov, A., et al.: "Microquasar V404 Cyg /GS 2023+338: MASTER optical observations during the June and December 2015 super-outbursts", 2019, New Astronomy, 72, 42.

Lipunov, V. M., Kuznetsov, A. S., Gorbovskoy, E. S., et al.: "V404 CYG/GS 2023+338: Monitoring in the Optical with Robotic Telescopes of the MASTER Global Network during the 2015 Superburst", 2019, Astronomy Reports, 63, 534.

Macaulay, E., Nichol, R. C., Bacon, D., et al.: "First cosmological results using Type Ia supernovae from the Dark Energy Survey: measurement of the Hubble constant", 2019, Monthly Notices of the RAS, 486, 2184.

Maccarone, T. J., Nelson, T. J., Brown, P. J., et al.: "Unconventional origin of supersoft X-ray emission from a white dwarf binary", 2018, Nature Astronomy, 3, 173.

Macri, L. M., Kraan-Korteweg, R. C., Lambert, T., et al.: "The 2MASS Redshift Survey in the Zone of Avoidance", 2019, Astrophysical Journals, 245, 6.

Mahoro, A., Pović, M., Nkundabakura, P., Nyiransengiyumva, B., & Väisänen, P.: "Star formation in far-IR AGN and non-AGN galaxies in the green valley - II. Morphological analysis", 2019, Monthly Notices of the RAS, 485, 452.

Manick, R., Kamath, D., Van Winckel, H., et al.: "Spectroscopic binaries RV Tauri and DF Cygni", 2019, Astronomy and Astrophysics, 628, A40.

Mason, P. A., Wells, N. K., Motsoaledi, M., Szkody, P., & Gonzalez, E.: "CRTS J035010.7 + 323230, a new eclipsing polar in the cataclysmic variable period gap", 2019, Monthly Notices of the RAS, 488, 2881.

Masters, K. L., Stark, D. V., Pace, Z. J., et al.: "H I-MaNGA: H I follow-up for the MaNGA survey", 2019, Monthly Notices of the RAS, 488, 3396.

McBrien, O. R., Smartt, S. J., Chen, T.-W., et al.: "SN2018kzr: A Rapidly Declining Transient from the Destruction of a White Dwarf", 2019, Astrophysical Journal Letters, 885, L23.

McNeill, A., Mommert, M., Trilling, D. E., Llama, J., & Skiff, B.: "Asteroid Photometry from the Transiting Exoplanet Survey Satellite: A Pilot Study", 2019, Astrophysical Journals, 245, 29.

Mellon, S. N., Mamajek, E. E., Zwintz, K., et al.: "Discovery of δ Scuti Pulsations in the Young Hybrid Debris Disk Star HD 156623", 2019, Astrophysical Journal, 870, 36.

Mellon, S. N., Mamajek, E. E., Stuik, R., et al.: "Bright Southern Variable Stars in the bRing Survey", 2019, Astrophysical Journals, 244, 15.

Menzies, J. W., Whitelock, P. A., Feast, M. W., & Matsunaga, N.: "Luminous AGB variables in the dwarf irregular galaxy, NGC 3109", 2019, Monthly Notices of the RAS, 483, 5150.

Miniutti, G., Saxton, R. D., Giustini, M., et al.: "Nine-hour X-ray quasi-periodic eruptions from a low-mass black hole galactic nucleus", 2019, New Astronomy, 573, 381.

Miszalski, B., Manick, R., Van Winckel, H., & Mikołajewska, J.: "The post-common-envelope binary nucleus of the planetary nebula IC 4776: neither an anomalously long orbital period nor a Wolf-Rayet binary", 2019, Monthly Notices of the RAS, 487, 1040.

Miszalski, B., Manick, R., Rauch, T., et al.: "Two's company, three's a crowd: SALT reveals the likely triple nature of the nucleus of the extreme abundance discrepancy factor planetary nebula Sp 3", 2019, Publications of the Astron. Soc. of Australia, 36, e042.

Miszalski, B., Manick, R., Van Winckel, H., & Escorza, A.: "The post-common-envelope X-ray binary nucleus of the planetary nebula NGC 2392", 2019, Publications of the Astron. Soc. of Australia, 36, e018.

Mogotsi, K. M., & Romeo, A. B.: "The stellar velocity dispersion in nearby spirals: radial profiles and correlations", 2019, Monthly Notices of the RAS, 489, 3797.

Molaro, M., Davé, R., Hassan, S., Santos, M. G., & Finlator, K.: "Artist: fast radiative transfer for large-scale simulations of the epoch of reionization", 2019, Monthly Notices of the RAS, 489, 5594.

Monageng, I. M., Coe, M. J., Townsend, L. J., et al.: “The SMC X-ray binary SXP4.78: a new Type II outburst and the identification and study of the optical counterpart”, 2019, Monthly Notices of the RAS, 485, 4617.

Monageng, I. M., Coe, M. J., Kennea, J. A., et al.: “An X-ray and optical study of the outbursting behaviour of the SMC Be X-ray binary SXP 91.1”, 2019, Monthly Notices of the RAS, 489, 993.

Muñoz-Darias, T., Jiménez-Ibarra, F., Panizo-Espinar, G., et al.: “Hard-state Accretion Disk Winds from Black Holes: The Revealing Case of MAXI J1820+070”, 2019, Astrophysical Journal Letters, 879, L4.

Nagakane, M., Lee, C.-H., Koshimoto, N., et al.: “OGLE-2015-BLG-1649Lb: A Gas Giant Planet around a Low-mass Dwarf”, 2019, Astronomical Journal, 158, 212.

Oknyansky, V. L., Winkler, H., Tsygankov, S. S., et al.: “New changing look case in NGC 1566”, 2019, Monthly Notices of the RAS, 483, 558.

Pace, Z. J., Tremonti, C., Chen, Y., et al.: “Resolved and Integrated Stellar Masses in the SDSS-IV/MaNGA Survey. II. Applications of PCA-based Stellar Mass Estimates”, 2019, Astrophysical Journal, 883, 83.

Pace, Z. J., Tremonti, C., Chen, Y., et al.: “Resolved and Integrated Stellar Masses in the SDSS-IV/MaNGA Survey. I. PCA Spectral Fitting and Stellar Mass-to-light Ratio Estimates”, 2019, Astrophysical Journal, 883, 82.

Paice, J. A., Gandhi, P., Charles, P. A., et al.: “Puzzling blue dips in the black hole candidate Swift J1357.2 - 0933, from ULTRACAM, SALT, ATCA, Swift, and NuSTAR”, 2019, Monthly Notices of the RAS, 488, 512.

Panopoulou, G. V., Tassis, K., Skalidis, R., et al.: “Demonstration of Magnetic Field Tomography with Starlight Polarization toward a Diffuse Sightline of the ISM”, 2019, Astrophysical Journal, 872, 56.

Paterson, K., Woudt, P. A., Warner, B., et al.: “High-speed photometry of faint cataclysmic variables - IX. Targets from multiple transient surveys”, 2019, Monthly Notices of the RAS, 486, 2422.

Proshina, I. S., Kniazev, A. Y., & Sil’chenko, O. K.: “Star-forming Rings in Lenticular Galaxies: Origin of the Gas”, 2019, Astronomical Journal, 158, 5.

Rafieferantsoa, M., Davé, R., & Naab, T.: “MUFASA: Timescales for H I consumption and SFR depletion of satellite galaxies in groups”, 2019, Monthly Notices of the RAS, 486, 5184.

Randriamanakoto, Z., Väisänen, P., Ryder, S. D., & Ranaivomanana, P.: “Young massive clusters in the interacting LIRG Arp 299: evidence for the dependence of star cluster formation and evolution on environment”, 2019, Monthly Notices of the RAS, 482, 2530.

Reddy, V., Kelley, M. S., Farnocchia, D., et al.: “Near-Earth asteroid 2012 TC4 observing campaign: Results from a global planetary defense exercise”, 2019, Icarus, 326, 133.

Rennehan, D., Babul, A., Hopkins, P. F., Davé, R., & Moa, B.: “Dynamic localized turbulent diffusion and its impact on the galactic ecosystem”, 2019, Monthly Notices of the RAS, 483, 3810.

Rodriguez, J. E., Eastman, J. D., Zhou, G., et al.: “KELT-24b: A 5M _J Planet on a 5.6 day Well-aligned Orbit around the Young V = 8.3 F-star HD 93148”, 2019, Astronomical Journal, 158, 197.

Rodríguez Montero, F., Davé, R., Wild, V., Anglés-Alcázar, D., & Narayanan, D.: “Mergers, starbursts, and quenching in the SIMBA simulation”, 2019, Monthly Notices of the RAS, 490, 2139.

Schaefer, A. L., Tremonti, C., Pace, Z., et al.: “SDSS-IV MaNGA: Evidence for Enriched Accretion onto Satellite Galaxies in Dense Environments”, 2019, Astrophysical Journal, 884, 156.

Schröder, A. C., Flöer, L., Winkel, B., & Kerp, J.: “EZOA - a catalogue of EBHIS H I-detected galaxies in the northern Zone of Avoidance”, 2019, Monthly Notices of the RAS, 489, 2907.

Schröder, A. C., van Driel, W., & Kraan-Korteweg, R. C.: “A zone of avoidance catalogue of 2MASS bright galaxies - I. Sample description and analysis”, 2019, Monthly Notices of the RAS, 482, 5167.

Sickafoose, A. A., Bosh, A. S., Levine, S. E., et al.: “A stellar occultation by Vanth, a satellite of (90482) Orcus”, 2019, Icarus, 319, 657.

Titus, N., Stappers, B. W., Morello, V., et al.: “Targeted search for young radio pulsars in the SMC: discovery of two new pulsars”, 2019, Monthly Notices of the RAS, 487, 4332.

Tsapras, Y., Cassan, A., Ranc, C., et al.: “An analysis of binary microlensing event OGLE-2015-BLG-0060”, 2019, Monthly Notices of the RAS, 487, 4603.

Vafaei Sadr, A., Vos, E. E., Bassett, B. A., et al.: “DEEPSOURCE: point source detection using deep learning”, 2019, Monthly Notices of the RAS, 484, 2793.

van Soelen, B., Komin, N., Kniazev, A., & Väisänen, P.: “The orbital parameters of the gamma-ray binary LMC P3†”, 2019, Monthly Notices of the RAS, 484, 4347.

Westfall, K. B., Cappellari, M., Bershady, M. A., et al.: “The Data Analysis Pipeline for the SDSS-IV MaNGA IFU Galaxy Survey: Overview”, 2019, Astronomical Journal, 158, 231.

Whitelock, P. A.: “Obituary, Michael William Feast 1926-2019”, 2019, Monthly Notes of the Astronomical Society of South Africa, 78, 54.

Wilson, J. C., Hearty, F. R., Skrutskie, M. F., et al.: “The Apache Point Observatory Galactic Evolution Experiment (APOGEE) Spectrographs”, 2019, Publications of the ASP, 131, 055001.

Wu, X., McQuinn, M., Kannan, R., et al.: “Imprints of temperature fluctuations on the z ⍰ 5 Lyman-α forest: a view from radiation-hydrodynamic simulations of reionization”, 2019, Monthly Notices of the RAS, 490, 3177.

Yan, R., Chen, Y., Lazarz, D., et al.: “SDSS-IV MaStar: A Large and Comprehensive Empirical Stellar Spectral Library—First Release”, 2019, Astrophysical Journal, 883, 175.

Yao, X., Pepper, J., Gaudi, B. S., et al.: “Precovery of Transiting Exoplanet Survey Satellite Single Transits with Kilodegree Extremely Little Telescope”, 2019, Astronomical Journal, 157, 37.

You, S., Zhang, Q., Ma, L., Xu, M., & Lin, H.: “Treatment and Reuse of Black Water by Novel Energy-saving Shaft/Anaerobic /Anoxic/ Aerobic (S/A/A/O) System: A Novel Energy-saving Shaft/Anaerobic /Anoxic/ Aerobic (S/A/A/O) System for black water”, 2019, E3S Web of Conferences, 117, 00009.

Yung, L. Y. A., Somerville, R. S., Popping, G., et al.: “Semi-analytic forecasts for JWST - II. Physical properties and scaling relations for galaxies at z = 4-10”, 2019, Monthly Notices of the RAS, 490, 2855.

Yung, L. Y. A., Somerville, R. S., Finkelstein, S. L., Popping, G., & Davé, R.: “Semi-analytic forecasts for JWST - I. UV luminosity functions at z = 4-10”, 2019, Monthly Notices of the RAS, 483, 2983.

Zhou, G., Huang, C. X., Bakos, G. Á., et al.: “Two New HATNet Hot Jupiters around A Stars and the First Glimpse at the Occurrence Rate of Hot Jupiters from TESS”, 2019, Astronomical Journal, 158, 141.

Zwintz, K., Reese, D. R., Neiner, C., et al.: “Revisiting the pulsational characteristics of the exoplanet host star β Pictoris”, 2019, Astronomy and Astrophysics, 627, A28.

PUBLICATIONS OF NON-SAAO RESEARCHERS AND BASED ON DATA OBTAINED WITH SAAO OR SAAO-HOSTED FACILITIES

Afsariardchi, N., Moon, D.-S., Drout, M. R., et al.: "KSP-SN-2016kf: A Long-rising H-rich Type II Supernova with Unusually High ⁵⁶Ni Mass Discovered in the KMTNet Supernova Program", 2019, Astrophysical Journal, 881, 22.

Angus, C. R., Smith, M., Sullivan, M., et al.: "Superluminous supernovae from the Dark Energy Survey", 2019, Monthly Notices of the RAS, 487, 2215.

Appourchaux, T., & Corbard, T.: "Searching for g modes. II. Unconfirmed g-mode detection in the power spectrum of the time series of round-trip travel time", 2019, Astronomy and Astrophysics, 624, A106.

Barkaoui, K., Burdanov, A., Hellier, C., et al.: "Discovery of Three New Transiting Hot Jupiters: WASP-161 b, WASP-163 b, and WASP-170 b", 2019, Astronomical Journal, 157, 43.

Bartos, I., Lee, K. H., Corsi, A., Márka, Z., & Márka, S.: "Radio forensics could unmask nearby off-axis gamma-ray bursts", 2019, Monthly Notices of the RAS, 485, 4150.

Black, C. S., Fesen, R. A., & Parrent, J. T.: "Narrow transient absorptions in late-time optical spectra of type Ia supernovae: evidence for large clumps of iron-rich ejecta?", 2019, Monthly Notices of the RAS, 483, 1114.

Boettcher, E., Gallagher, J. S., & Zweibel, E. G.: "A Dynamical Study of Extraplanar Diffuse Ionized Gas in NGC 5775", 2019, Astrophysical Journal, 885, 160.

Bowman, D. M., & Holdsworth, D. L.: "Adaptive elliptical aperture photometry: A software package for high-cadence ground-based photometry. I. Application to rapid oscillators observed from SAAO", 2019, Astronomy and Astrophysics, 629, A21.

Braga, V. F., Stetson, P. B., Bono, G., et al.: "New near-infrared JHK_s light-curve templates for RR Lyrae variables", 2019, Astronomy and Astrophysics, 625, A1.

Brown, P. J., Hosseinzadeh, G., Jha, S. W., et al.: "Red and Reddened: Ultraviolet through Near-infrared Observations of Type Ia Supernova 2017erp", 2019, Astrophysical Journal, 877, 152.

Calchi Novati, S., Suzuki, D., Udalski, A., et al.: "Spitzer Microlensing Parallax for OGLE-2016-BLG-1067: A Sub-Jupiter Orbiting an M Dwarf in the Disk", 2019, Astronomical Journal, 157, 121.

Carry, B., Vachier, F., Berthier, J., et al.: "Homogeneous internal structure of CM-like asteroid (41) Daphne", 2019, Astronomy and Astrophysics, 623, A132.

Chaplin, W. J., Howe, R., Basu, S., et al.: "Sensitivity of low-degree solar p modes to active and ephemeral regions: frequency shifts back to the Maunder minimum", 2019, Monthly Notices of the RAS, 489, L86.

Chung, S.-J., Gould, A., Skowron, J., et al.: "Spitzer Microlensing of MOA-2016-BLG-231L: A Counter-rotating Brown Dwarf Binary in the Galactic Disk", 2019, Astrophysical Journal, 871, 179.

Coti Zelati, F., Papitto, A., de Martino, D., et al.: "Prolonged sub-luminous state of the new transitional pulsar candidate CXOU J110926.4-650224", 2019, Astronomy and Astrophysics, 622, A211.

Czerny, B., Olejak, A., Rałowski, M., et al.: "Time Delay Measurement of Mg II Line in CTS C30.10 with SALT", 2019, Astrophysical Journal, 880, 46.

Díez Alonso, E., Caballero, J. A., Montes, D., et al.: "CARMENES input catalogue of M dwarfs. IV. New rotation periods from photometric time series", 2019, Astronomy and Astrophysics, 621, A126.

Farah, W., Flynn, C., Bailes, M., et al.: "Five new real-time detections of fast radio bursts with UTMOST", 2019, Monthly Notices of the RAS, 488, 2989.

Fremling, C., Ko, H., Dugas, A., et al.: "ZTF18aalrxas: A Type IIb Supernova from a Very Extended Low-mass Progenitor", 2019, Astrophysical Journal Letters, 878, L5.

Furuta, T., Kaneda, H., Kokusho, T., et al.: "Extinction and dust/gas ratio in the H I ridge region of the LMC based on the IRSF/SIRIUS near-infrared survey", 2019, Publications of the ASJ, 71, 95.

Gajdoš, P., Vaňko, M., Jakubík, M., et al.: "WASP-92, WASP-93, and WASP-118: transit timing variations and long-term stability of the systems", 2019, Monthly Notices of the RAS, 485, 3580.

Galbany, L., Ashall, C., Höflich, P., et al.: "Evidence for a Chandrasekhar-mass explosion in the Ca-strong 1991bg-like type Ia supernova 2016hnk", 2019, Astronomy and Astrophysics, 630, A76.

Gałan, C., Mikołajewska, J., Monard, B., et al.: "Hen 3-160 - the First Symbiotic Binary with Mira Variable S Star", 2019, Acta Astronomica, 69, 25.

González, J. F., Briquet, M., Przybilla, N., et al.: "HD 96446: a long-period binary with a strongly magnetic He-rich primary with β Cephei pulsations", 2019, Astronomy and Astrophysics, 626, A94.

Gómez Maqueo Chew, Y., Hebb, L., Stempels, H. C., et al.: "Fundamental properties of the pre-main sequence eclipsing stars of MML 53 and the mass of the tertiary", 2019, Astronomy and Astrophysics, 623, A23.

Han, C., Yee, J. C., Udalski, A., et al.: "Spectroscopic Mass and Host-star Metallicity Measurements for Newly Discovered Microlensing Planet OGLE-2018-BLG-0740Lb", 2019, Astronomical Journal, 158, 102.

Han, C., Bond, I. A., Udalski, A., et al.: "OGLE-2018-BLG-0022: First Prediction of an Astrometric Microlensing Signal from a Photometric Microlensing Event", 2019, Astrophysical Journal, 876, 81.

Han, C., Bennett, D. P., Udalski, A., et al.: "OGLE-2018-BLG-1011Lb,c: Microlensing Planetary System with Two Giant Planets Orbiting a Low-mass Star", 2019, Astronomical Journal, 158, 114.

Hanuš, J., Marsset, M., Vernazza, P., et al.: "The shape of (7) Iris as evidence of an ancient large impact?", 2019, Astronomy and Astrophysics, 624, A121.

Hashemi, S. A., Javadi, A., & van Loon, J. T.: "From evolved stars to the evolution of IC 1613", 2019, Monthly Notices of the RAS, 483, 4751.

Hellier, C., Anderson, D. R., Bouchy, F., et al.: "New transiting hot Jupiters discovered by WASP-South, Euler/CORALIE, and TRAPPIST-South", 2019, Monthly Notices of the RAS, 482, 1379.

Hellier, C., Anderson, D. R., Barkaoui, K., et al.: "WASP-South hot Jupiters: WASP-178b, WASP-184b, WASP-185b, and WASP-192b", 2019, Monthly Notices of the RAS, 490, 1479.

Hill, C. A., Folsom, C. P., Donati, J.-F., et al.: "Erratum: Magnetic topologies of young suns: the weak-line T Tauri stars TWA 6 and TWA 8A", 2019, Monthly Notices of the RAS, 486, 5526.

Holdsworth, D. L., Saio, H., & Kurtz, D. W.: "HD 42659: the only known roAp star in a spectroscopic binary observed with B photometry, TESS, and SALT", 2019, Monthly Notices of the RAS, 489, 4063.

Holoien, T. W.-S., Brown, J. S., Vallely, P. J., et al.: "The ASAS-SN bright supernova catalogue - IV. 2017", 2019, Monthly Notices of the RAS, 484, 1899.

Holoien, T. W.-S., Vallely, P. J., Auchettl, K., et al.: "Discovery and Early Evolution of ASASSN-19bt, the First TDE Detected by TESS", 2019, Astrophysical Journal, 883, 111.

Hong, K., Lee, J. W., Kim, S.-L., et al.: "Absolute Dimensions and Apsidal Motions of Three Binary Systems in the Large Magellanic Cloud", 2019, Astronomical Journal, 158, 185.

Hosseinzadeh, G., Cowperthwaite, P. S., Gomez, S., et al.: "Follow-up of the Neutron Star Bearing Gravitational-wave Candidate Events S190425z and S190426c with MMT and SOAR", 2019, Astrophysical Journal Letters, 880, L4.

Hwang, K.-H., Ryu, Y.-H., Kim, H.-W., et al.: "KMT-2016-BLG-1107: A New Hollywood-planet Close/Wide Degeneracy", 2019, Astronomical Journal, 157, 23.

Inno, L., Urbaneja, M. A., Matsunaga, N., et al.: "First metallicity determination from near-infrared spectra for five obscured Cepheids discovered in the inner disc", 2019, Monthly Notices of the RAS, 482, 83.

Jackman, J. A. G., Wheatley, P. J., Bayliss, D., et al.: "NGTS-7Ab: an ultrashort-period brown dwarf transiting a tidally locked and active M dwarf", 2019, Monthly Notices of the RAS, 489, 5146.

Jayasinghe, T., Stanek, K. Z., Kochanek, C. S., et al.: "The ASAS-SN catalogue of variable stars III: variables in the southern TESS continuous viewing zone", 2019, Monthly Notices of the RAS, 485, 961.

Jones, M. I., Brahm, R., Espinoza, N., et al.: "HD 2685 b: a hot Jupiter orbiting an early F-type star detected by TESS", 2019, Astronomy and Astrophysics, 625, A16.

Jung, Y. K., Gould, A., Udalski, A., et al.: "Spitzer Parallax of OGLE-2018-BLG-0596: A Low-mass-ratio Planet around an M Dwarf", 2019, Astronomical Journal, 158, 28.

Jung, Y. K., Gould, A., Zang, W., et al.: “KMT-2017-BLG-0165Lb: A Super-Neptune-mass Planet Orbiting a Sun-like Host Star”, 2019, Astronomical Journal, 157, 72.

Jørgensen, A. C. S., & Weiss, A.: “Overcoming the structural surface effect with a realistic treatment of turbulent convection in 1D stellar models”, 2019, Monthly Notices of the RAS, 488, 3463.

Kahraman Aliçavuş, F., & Aliçavuş, F.: “Detailed spectroscopic and photometric study of three detached eclipsing binaries”, 2019, Monthly Notices of the RAS, 488, 5279.

Kleyna, J. T., Hainaut, O. R., Meech, K. J., et al.: “The Sporadic Activity of (6478) Gault: A YORP-driven Event?”, 2019, Astrophysical Journal Letters, 874, L20.

Koen, C.: “Multifilter time-series observations of three short period ATLAS variable stars”, 2019, Monthly Notices of the RAS, 490, 1283.

Kwon, Y. G., Ishiguro, M., Kwon, J., et al.: “Near-infrared polarimetric study of near-Earth object 252P/LINEAR: an implication of scattered light from the evolved dust particles”, 2019, Astronomy and Astrophysics, 629, A121.

Latković, O., Cséki, A., Djurašević, G., et al.: “Long-term Spot Stability in the Post-common-envelope Binary QS Vir”, 2019, Astronomical Journal, 157, 3.

Lee, Y., Moon, D.-S., Kim, S. C., et al.: “KSP-OT-201611a: A Distant Population II Dwarf Nova Candidate Discovered by the KMTNet Supernova Program”, 2019, Astrophysical Journal, 880, 109.

Li, K., Xia, Q.-Q., Michel, R., et al.: “Contact binaries at the short period cut-off - I. Statistics and the first photometric investigations of 10 totally eclipsing systems”, 2019, Monthly Notices of the RAS, 485, 4588.

Li, S.-S., Zang, W., Udalski, A., et al.: “OGLE-2017-BLG-1186: first application of asteroseismology and Gaussian processes to microlensing”, 2019, Monthly Notices of the RAS, 488, 3308.

Mallonn, M., von Essen, C., Herrero, E., et al.: “Ephemeris refinement of 21 hot Jupiter exoplanets with high timing uncertainties”, 2019, Astronomy and Astrophysics, 622, A81.

Martin, D. V., Triaud, A. H. M. J., Udry, S., et al.: “The BEBOP radial-velocity survey for circumbinary planets. I. Eight years of CORALIE observations of 47 single-line eclipsing binaries and abundance constraints on the masses of circumbinary planets”, 2019, Astronomy and Astrophysics, 624, A68.

Martone, R., Guidorzi, C., Mundell, C. G., et al.: “A robotic pipeline for fast GRB followup with the Las Cumbrés observatory network”, 2019, Experimental Astronomy, 48, 25.

Meza, N., Prieto, J. L., Clocchiatti, A., et al.: “The extraplanar type II supernova ASASSN-14jb in the nearby edge-on galaxy ESO 467-G051”, 2019, Astronomy and Astrophysics, 629, A57.

Molina, C. N., Borissova, J., Catelan, M., et al.: “Long-term stellar variability in the Galactic Centre region”, 2019, Monthly Notices of the RAS, 482, 5567.

Moschou, S.-P., Drake, J. J., Cohen, O., et al.: “The Stellar CME-Flare Relation: What Do Historic Observations Reveal?”, 2019, Astrophysical Journal, 877, 105.

Nagatomo, S., Nagata, T., & Nishiyama, S.: “Interstellar extinction law toward the Galactic center. IV. J, H, and K_s bands from VVV red clump stars”, 2019, Publications of the ASJ, 71, 106.

Narayan, G., Matheson, T., Saha, A., et al.: “Subpercent Photometry: Faint DA White Dwarf Spectrophotometric Standards for Astrophysical Observatories”, 2019, Astrophysical Journals, 241, 20.

Navarro-Meza, S., Mommert, M., Trilling, D. E., et al.: “First Results from the Rapid-response Spectrophotometric Characterization of Near-Earth Objects Using RATIR”, 2019, Astronomical Journal, 157, 190.

Nayak, O., Meixner, M., Sewiło, M., et al.: “ALMA Reveals Kinematics of Super Star Cluster Candidate H72.97-69.39 in LMC-N79”, 2019, Astrophysical Journal, 877, 135.

Newton, E. R., Mann, A. W., Tofflemire, B. M., et al.: “TESS Hunt for Young and Maturing Exoplanets (THYME): A Planet in the 45 Myr Tucana-Horologium Association”, 2019, Astrophysical Journal Letters, 880, L17.

Nicholl, M., Blanchard, P. K., Berger, E., et al.: “The tidal disruption event AT2017eqx: spectroscopic evolution from hydrogen rich to poor suggests an atmosphere and outflow”, 2019, Monthly Notices of the RAS, 488, 1878.

Nielsen, L. D., Bouchy, F., Turner, O. D., et al.: “WASP-169, WASP-171, WASP-175, and WASP-182: three hot Jupiters and one bloated sub-Saturn mass planet discovered by WASP-South”, 2019, Monthly Notices of the RAS, 489, 2478.

Nogueras-Lara, F., Schödel, R., Najarro, F., et al.: “Variability of the near-infrared extinction curve towards the Galactic centre”, 2019, Astronomy and Astrophysics, 630, L3.

Nogueras-Lara, F., Schödel, R., Gallego-Calvente, A. T., et al.: “GALACTICNUCLEUS: A high-angular-resolution JHK$_s$ imaging survey of the Galactic centre. II. First data release of the catalogue and the most detailed CMDs of the GC”, 2019, Astronomy and Astrophysics, 631, A20.

OGLE Collaboration, Mróz, P., Udalski, A., Bennett, et al.: “Two new free-floating or wide-orbit planets from microlensing”, 2019, Astronomy and Astrophysics, 622, A201.

Ogle, P. M., Jarrett, T., Lanz, L., et al.: “A Break in Spiral Galaxy Scaling Relations at the Upper Limit of Galaxy Mass”, 2019, Astrophysical Journal Letters, 884, L11.

Ohyama, Y., Sakamoto, K., Aalto, S., & Gallagher, J. S.: “Dusty Superwind from a Galaxy with a Compact Obscured Nucleus: Optical Spectroscopic Study of NGC 4418”, 2019, Astrophysical Journal, 871, 191.

Onozato, H., Ita, Y., Nakada, Y., & Nishiyama, S.: “The age and metallicity dependence of the near-infrared magnitudes of red clump stars”, 2019, Monthly Notices of the RAS, 486, 5600.

Osborn, H. P., Kenworthy, M., Rodriguez, J. E., et al.: “The PDS 110 observing campaign - photometric and spectroscopic observations reveal eclipses are aperiodic”, 2019, Monthly Notices of the RAS, 485, 1614.

Pallottini, A., Ferrara, A., Decataldo, D., et al.: “Deep into the structure of the first galaxies: SERRA views”, 2019, Monthly Notices of the RAS, 487, 1689.

Parikh, A. S., Hernández Santisteban, J. V., Wijnands, R., & Page, D.: “Multiwavelength Observations of MASTER OT 075353.88+174907.6: A Likely Superoutburst of a Long Period Dwarf Nova System”, 2019, Revista Mexicana de Astronomia y Astrofisica, 55, 55.

Pastorello, A., Reguitti, A., Morales-Garoffolo, A., et al.: “A luminous stellar outburst during a long-lasting eruptive phase first, and then SN IIn 2018cnf”, 2019, Astronomy and Astrophysics, 628, A93.

Paunzen, E., Bernhard, K., Hümmerich, S., et al.: “Search for stellar spots in field blue horizontal-branch stars”, 2019, Astronomy and Astrophysics, 622, A77.

Poleski, R., Penny, M., Gaudi, B. S., et al.: “Photometry of K2 Campaign 9 bulge data”, 2019, Astronomy and Astrophysics, 627, A54.

Poleski, R., & Yee, J. C.: “Modeling microlensing events with MulensModel”, 2019, Astronomy and Computing, 26, 35.

Prentice, S. J., Ashall, C., James, P. A., et al.: “Investigating the properties of stripped-envelope supernovae; what are the implications for their progenitors?”, 2019, Monthly Notices of the RAS, 485, 1559.

Price, D. C., Foster, G., Geyer, M., et al.: “A fast radio burst with frequency-dependent polarization detected during Breakthrough Listen observations”, 2019, Monthly Notices of the RAS, 486, 3636.

Prudil, Z., Skarka, M., Liška, J., Grebel, E. K., & Lee, C.-U.: “Candidates for RR Lyrae in binary systems from the OGLE Galactic bulge survey”, 2019, Monthly Notices of the RAS, 487, L1.

Pruzhinskaya, M. V., Malanchev, K. L., Kornilov, M. V., et al.: “Anomaly detection in the Open Supernova Catalog”, 2019, Monthly Notices of the RAS, 489, 3591.

Quinn, S. N., Becker, J. C., Rodriguez, J. E., et al.: “Near-resonance in a System of Sub-Neptunes from TESS”, 2019, Astronomical Journal, 158, 177.

Ranc, C., Bennett, D. P., Hirao, Y., et al.: “OGLE-2015-BLG-1670Lb: A Cold Neptune beyond the Snow Line in the Provisional WFIRST Microlensing Survey Field”, 2019, Astronomical Journal, 157, 232.

Ren, J., Lin, D.-B., Zhang, L.-L., et al.: “A Pulsar Wind Nebula Embedded in the Kilonova AT 2017gfo Associated with GW170817/GRB 170817A”, 2019, Astrophysical Journal, 885, 60.

Rendle, B. M., Buldgen, G., Miglio, A., et al.: “AIMS - a new tool for stellar parameter determinations using asteroseismic constraints”, 2019, Monthly Notices of the RAS, 484, 771.

Ryu, Y.-H., Hwang, K.-H., Gould, A., et al.: “KMT-2018-BLG-1990Lb: A Nearby Jovian Planet From A Low-cadence Microlensing Field”, 2019, Astronomical Journal, 158, 151.

Schanche, N., Collier Cameron, A., Almenara, J. M., et al.: “SuperWASP dispositions and false positive catalogue”, 2019, Monthly Notices of the RAS, 488, 4905.

Scherrer, P. H., & Gough, D. O.: “A Critical Evaluation of Recent Claims Concerning Solar Rotation”, 2019, Astrophysical Journal, 877, 42.

Shappee, B. J., Holoien, T. W.-S., Drout, M. R., et al.: “Seeing Double: ASASSN-18bt Exhibits a Two-component Rise in the Early-time K2 Light Curve”, 2019, Astrophysical Journal, 870, 13.

Shin, I.-G., Ryu, Y.-H., Yee, J. C., et al.: “Two Jupiter-mass Planets Discovered by the KMTNet Survey in 2017”, 2019, Astronomical Journal, 157, 146.

Shvartzvald, Y., Yee, J. C., Skowron, J., et al.: “Spitzer Microlensing Parallax for OGLE-2017-BLG-0896 Reveals a Counter-rotating Low-mass Brown Dwarf”, 2019, Astronomical Journal, 157, 106.

Sil’chenko, O. K., Moiseev, A. V., & Egorov, O. V.: “The Gas Kinematics, Excitation, and Chemistry, in Connection with Star Formation, in Lenticular Galaxies”, 2019, Astrophysical Journals, 244, 6.

Silvotti, R., Uzundag, M., Baran, A. S., et al.: “High-degree gravity modes in the single sdB star HD 4539”, 2019, Monthly Notices of the RAS, 489, 4791.

Singh, M., Misra, K., Sahu, D. K., et al.: “Observational properties of a Type Ib supernova MASTER OT J120451.50+265946.6 in NGC 4080”, 2019, Monthly Notices of the RAS, 485, 5438.

Smits, D. P., & Skelton, P. L.: “Characterization of eclipsing binaries in High Latitude Field 356”, 2019, New Astronomy, 67, 53.

Spiniello, C., Sergeyev, A. V., Marchetti, L., et al.: “Spectroscopic confirmation and modelling of two lensed quadruple quasars in the Dark Energy Survey public footprint”, 2019, Monthly Notices of the RAS, 485, 5086.

Stetson, P. B., Pancino, E., Zocchi, A., Sanna, N., & Monelli, M.: “Homogeneous photometry - VII. Globular clusters in the Gaia era”, 2019, Monthly Notices of the RAS, 485, 3042.

Street, R. A., Bachelet, E., Tsapras, Y., et al.: “OGLE-2018-BLG-0022: A Nearby M-dwarf Binary”, 2019, Astronomical Journal, 157, 215.

Sudou, H., Omodaka, T., Murakami, K., et al.: “Annual parallax measurements of a semi-regular variable star SV Pegasus with VERA”, 2019, Publications of the ASJ, 71, 16.

Sun, W., de Grijs, R., Deng, L., & Albrow, M. D.: “Stellar Rotation and the Extended Main-sequence Turnoff in the Open Cluster NGC 5822”, 2019, Astrophysical Journal, 876, 113.

Tamaoki, S., Sugitani, K., Nguyen-Luong, Q., et al.: “Magnetic Stability of Massive Star-forming Clumps in RCW 106”, 2019, Astrophysical Journal Letters, 875, L16.

Temple, L. Y., Hellier, C., Anderson, D. R., et al.: “WASP-180Ab: Doppler tomography of a hot Jupiter orbiting the primary star in a visual binary”, 2019, Monthly Notices of the RAS, 490, 2467.

Temple, L. Y., Hellier, C., Almleaky, Y., et al.: “WASP-190b: Tomographic Discovery of a Transiting Hot Jupiter”, 2019, Astronomical Journal, 157, 141.

Thomas, A. E. L., Chaplin, W. J., Davies, G. R., et al.: “Asteroseismic constraints on active latitudes of solar-type stars: HD 173701 has active bands at higher latitudes than the Sun”, 2019, Monthly Notices of the RAS, 485, 3857.

Tofflemire, B. M., Mathieu, R. D., & Johns-Krull, C. M.: “Accretion Kinematics in the T Tauri Binary TWA 3A: Evidence for Preferential Accretion onto the TWA 3A Primary”, 2019, Astronomical Journal, 158, 245.

Turner, O. D., Anderson, D. R., Barkaoui, K., et al.: “Three hot-Jupiters on the upper edge of the mass-radius distribution: WASP-177, WASP-181, and WASP-183”, 2019, Monthly Notices of the RAS, 485, 5790.

van Genderen, A. M., Lobel, A., Nieuwenhuijzen, H., et al.: “Pulsations, eruptions, and evolution of four yellow hypergiants”, 2019, Astronomy and Astrophysics, 631, A48.

Vanderburg, A., Huang, C. X., Rodriguez, J. E., et al.: “TESS Spots a Compact System of Super-Earths around the Naked-eye Star HR 858”, 2019, Astrophysical Journal Letters, 881, L19.

Vines, J. I., Jenkins, J. S., Acton, J. S., et al.: “NGTS-6b: an ultrashort period hot-Jupiter orbiting an old K dwarf”, 2019, Monthly Notices of the RAS, 489, 4125.

Wang, H., & Shi, Y.: “The deviation of optical variability of radio-quiet quasars from damped random walk”, 2019, Astrophysics and Space Science, 364, 27.

Wang, S., Jones, M., Shporer, A., et al.: “HD 202772A b: A Transiting Hot Jupiter around a Bright, Mildly Evolved Star in a Visual Binary Discovered by TESS”, 2019, Astronomical Journal, 157, 51.

West, R. G., Gillen, E., Bayliss, D., et al.: “NGTS-4b: A sub-Neptune transiting in the desert”, 2019, Monthly Notices of the RAS, 486, 5094.

Yan, W., Hickox, R. C., Hainline, K. N., et al.: “NuSTAR and Keck Observations of Heavily Obscured Quasars Selected by WISE”, 2019, Astrophysical Journal, 870, 33.

Yang, M., Bonanos, A. Z., Jiang, B.-W., et al.: “Evolved massive stars at low-metallicity. I. A source catalog for the Small Magellanic Cloud”, 2019, Astronomy and Astrophysics, 629, A91.

Yang, W.: “Rotating Solar Models with Low Metal Abundances as Good as Those with High Metal Abundances”, 2019, Astrophysical Journal, 873, 18.

Zajaček, M., Czerny, B., Martínez-Aldama, M. L., & Karas, V.: “Reverberation mapping of distant quasars: Time lag determination using different methods”, 2019, Astronomische Nachrichten, 340, 577.

Zechmeister, M., Dreizler, S., Ribas, I., et al.: “The CARMENES search for exoplanets around M dwarfs. Two temperate Earth-mass planet candidates around Teegarden’s Star”, 2019, Astronomy and Astrophysics, 627, A49.

NON-REFEREED PUBLICATIONS**

Balakin, F., Lipunov, V., Gorbovskoy, E., et al.: “GRB 190821A: MASTER VWFC syncronous optical observations”, 2019, GRB Coordinates Network, 25448, 1.

Balanutsa, P., Pogrosheva, T., Lipunov, V., et al.: “MASTER: two OT detection”, 2019, The Astronomer’s Telegram, 12583, 1.

Balanutsa, P., Lipunov, V., Buckley, D., et al.: “MASTER: new OT, ampl >5m”, 2019, The Astronomer’s Telegram, 12523, 1.

Balanutsa, P., Lipunov, V., Buckley, D., et al.: “MASTER-SAAO: outburst with ampl>4.9m”, 2019, The Astronomer’s Telegram, 13194, 1.

Balanutsa, P., Lipunov, V., Buckley, D., et al.: “Master: Psn in ESO174-005”, 2019, The Astronomer’s Telegram, 12412, 1.

Bowman, D. M., & Holdsworth, D. L.: “VizieR Online Data Catalog: TEA-Phot python code (Bowman+, 2019)”, 2019, VizieR Online Data Catalog, J/A+A/629/A21.

Buckley, D. A. H.: “Q: When is a pulsar not a neutron star? A: when its a white dwarf!”, 2019, Compact White Dwarf Binaries, 44.

Burleigh, M.: “The Next Generation Transit Survey”, 2019, Southern Horizons in Time-Domain Astronomy, 339, 22.

Erasmus, N., McNeill, A., Mommert, M., et al.: “Investigating Taxonomic Diversity of the Main Belt through KMTNET-SAAO and ATLAS Multi-band Photometry”, 2019, EPSC-DPS Joint Meeting 2019, 2019, EPSC-DPS2019-147.

Ershova, O., Gorbovskoy, E., Lipunov, V., et al.: “MASTER: 2 new OTs, amplitude more then 4m”, 2019, The Astronomer’s Telegram, 12549, 1.

Ershova, O., Pogrosheva, T., Lipunov, V., et al.: “MASTER: 2 CV outbursts”, 2019, The Astronomer’s Telegram, 12606, 1.

Ershova, O., Pogrosheva, T., Shumkov, V., et al.: “MASTER: bright optical transients”, 2019, The Astronomer’s Telegram, 12868, 1.

Ershova, O., Lipunov, V., Buckley, D., et al.: “Master: SN in ESO267-040”, 2019, The Astronomer’s Telegram, 12639, 1.

Genade, A.: “The South African Astronomical Observatory’s Stellar Occultation Program”, 2019, EPSC-DPS Joint Meeting 2019, 2019, EPSC-DPS2019-1320.

Gill, S., Maxted, P. F. L., Evans, J. A., et al.: “VizieR Online Data Catalog: EBLM J2349-32 photometry, RV and spectra (Gill+, 2019)”, 2019, VizieR Online Data Catalog, J/A+A/626/A119.

Gonzalez, S., & Krisciunas, K.: “Photometric Anaylsis of SN2018bgz.”, 2019, American Astronomical Society Meeting Abstracts #233, 233, 456.06.

Gorbovskoy, E., Gress, O., Lipunov, V., et al.: “MASTER: optical transients with amplitude more then 5.6 and 3.8m”, 2019, The Astronomer’s Telegram, 13364, 1.

Gorbovskoy, E., Lipunov, V., Kornilov, V., et al.: “MASTER: OT outburst detection inside LVC S190923y error-box”, 2019, The Astronomer’s Telegram, 13140, 1.

Gress, O., Lipunov, V., Balakin, F., et al.: “IceCube-190819A: MASTER analysis”, 2019, GRB Coordinates Network, 25412, 1.

Gress, O., Pogrosheva, T., Balanutsa, P., et al.: “MASTER: OT outbursts”, 2019, The Astronomer’s Telegram, 12758, 1.

Groot, P., Vreeswijk, P., Bloemen, S., et al.: “LIGO/Virgo S190814bv: MeerLICHT coverage second preliminary skymap”, 2019, GRB Coordinates Network, 25340, 1.

Hale, A., Berry, R., & Weiland, H.: “(6478) Gault”, 2019, Central Bureau Electronic Telegrams, 4594, 2.

Harbeck, D. R., Brown, T., Siverd, R., et al.: “The Las Cumbres Observatory’s Network of Robotic Echelle Spectrographs in 2019: Current status and next steps”, 2019, American Astronomical Society Meeting Abstracts #233, 233, 146.03.

Hartman, J. D., Bakos, G. A., Bayliss, D., et al.: “VizieR Online Data Catalog: RVs and light curves for HATS-60-HATS-69 (Hartman+, 2019)”, 2019, VizieR Online Data Catalog, J/AJ/157/55.

Hong, K., Lee, J. W., Kim, S.-L., et al.: “VizieR Online Data Catalog: Three binary systems in the Large Magellanic Cloud (Hong+, 2019)”, 2019, VizieR Online Data Catalog, J/AJ/158/185.

Husser, T.-O., & Hessman, F.: “Using Open Source Software and Open Standards for operating robotic telescopes”, 2019, Revista Mexicana de Astronomia y Astrofisica Conference Series, 51, 15.

Leeuw, L. L., & Holbrook, J.: “The Role of the IAU Gleaned From Oral Histories of Individuals Involved in Astronomy in South Africa”, 2019, Under One Sky: The IAU Centenary Symposium, 349, 240.

Lipunov, V., Gorbovskoy, E., Balakin, F., et al.: “GRB 190829A:: Global MASTER-net optical clear and polarization observations scheduler and some spiculations”, 2019, GRB Coordinates Network, 25573, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 584465880 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25051, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 588398821 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25475, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “LIGO/Virgo S190910d Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25694, 1.

Lipunov, V., Kornilov, V., Gorbovskoy, E., et al.: “S190602aq: MASTER OT detection”, 2019, GRB Coordinates Network, 24737, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 590335819: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25767, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 584804684 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25071, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “LIGO/Virgo S190814bv Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25322, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 584637077 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25063, 1.

Lipunov, V., Balakin, F., Gorbovskoy, E., et al.: “S190814bv: MASTER analysis of DECam-GROWTH candidates”, 2019, GRB Coordinates Network, 25370, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 586574612 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25260, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 590777160: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25800, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 588100239 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25428, 1.

Lipunov, V., Vlasenko, D., Gorbovskoy, E., et al.: “LIGO/Virgo S190814bv: MASTER prediscovery and postdiscovery observations DECam candidate DG19wxnjc/AT2019npv field”, 2019, GRB Coordinates Network, 25474, 1.

Lipunov, V., Kornilov, V., Gorbovskoy, E., et al.: “GRB 190531B: MASTER optical observation”, 2019, GRB Coordinates Network, 24707, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 597955752: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 26415, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “LIGO/Virgo S191105e: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 26184, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 583854113 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 24975, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “MAXI GRB190708.83 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25039, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 586305505 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25242, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 588350802 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25467, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 581889628 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 24781, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “GRB 191125B: MASTER-VWFC synchronous observation”, 2019, GRB Coordinates Network, 26299, 1.

Lipunov, V., Balakin, F., Gorbovskoy, E., et al.: “GRB 190829A: MASTER confirmation of GROND SN”, 2019, GRB Coordinates Network, 25652, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 588962322 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25590, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Integral GRB190919.99: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25787, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 584929684 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25074, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Swift GRB190718.2 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25083, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 584007338 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 24991, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 598648473: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 26533, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 589223981 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25637, 1.

Lipunov, V., Gorbovskoy, E., Svinkin, D., et al.: “GRB 190731A: no OT detected by MASTER”, 2019, GRB Coordinates Network, 25256, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Baksan Neutrino Observatory Alert 190703.21 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 24980, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 588115134 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25451, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 598543714: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 26523, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “GRB 191023A: MASTER optical observation”, 2019, GRB Coordinates Network, 26074, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 586800758 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25281, 1.

Lipunov, V., Gorbovskoy, E., Tyurina, N., et al.: “Baksan Neutrino Observatory Alert 190816.83 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25378, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 585864875 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25161, 1.

Lipunov, V., Balakin, F., Gorbovskoy, E., et al.: “GRB 190829A:: MASTER-net bright and decay OT detection”, 2019, GRB Coordinates Network, 25558, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 590610007: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25785, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Swift GRB 191221B: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 26536, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “IceCube Alert 190922.96: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25804, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Swift GRB191004.9: Global MASTER-Net OT detection”, 2019, GRB Coordinates Network, 25948, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 585007213 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25080, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “LIGO/Virgo S191205ah: MASTER OT detection”, 2019, GRB Coordinates Network, 26379, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 589060361 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25600, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “GRB 190928A: MASTER optical observations”, 2019, GRB Coordinates Network, 25867, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “GRB190915A: MASTER optical observation of BALROG Fermi GRB localization”, 2019, GRB Coordinates Network, 25759, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 585856427 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25156, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “LIGO/Virgo S190930t and S190930s: MASTER optical observation and optical transient”, 2019, GRB Coordinates Network, 25897, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 588185734 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25453, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “IceCube-191122A: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 26280, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “LIGO/Virgo S190924h: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25831, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “LIGO/Virgo S191215w: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 26440, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “LIGO/Virgo S190707q Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25022, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “LIGO/Virgo S191225aq: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 26584, 1.

Lipunov, V., Gorbovskoy, E., Tyurina, N., et al.: “Baksan Neutrino Observatory Alert 191102.06: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 26143, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 594523229: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 26172, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “LIGO/Virgo S190602aq Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 24721, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “MAXI GRB190804.33 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25267, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 584404689 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25050, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 586305505 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25243, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 581645543 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 24770, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Integral GRB190828.78 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25527, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “IceCube Alert 191001.84: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25910, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 587505927 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25357, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “HAWC Alert 190806.56 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25283, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 587392154 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25318, 1.

Lipunov, V., Balakin, F., Gorbovskoy, E., et al.: “Fermi GBM-190816: MASTER-Net optical observation report”, 2019, GRB Coordinates Network, 25446, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 586240252 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25234, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “LIGO/Virgo S190822c Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25440, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 581841498 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 24776, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 589487114 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25681, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “LIGO/Virgo S190829u Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25556, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Swift GRB191004.75: Global MASTER-Net OT detection”, 2019, GRB Coordinates Network, 25944, 1.

Lipunov, V., Gorbovskoy, E., Tyurina, N., et al.: “Baksan Neutrino Observatory Alert 191016.51: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 26014, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 594592184: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 26173, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 590621700: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25786, 1.

Lipunov, V., Gorbovskoy, E., Tyurina, N., et al.: “Baksan Neutrino Observatory Alert 190920.65: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25797, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “LIGO/Virgo S190923y: MASTER OT outburst detection inside NSBH merger error-box”, 2019, GRB Coordinates Network, 25855, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Fermi trigger No 591321287: Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25857, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “LIGO/Virgo S190814bv Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25354, 1.

Lipunov, V., Gorbovskoy, E., Kornilov, V., et al.: “Swift GRB190821.72 Global MASTER-Net observations report”, 2019, GRB Coordinates Network, 25429, 1.

Matsunaga, N., Feast, M. W., & Soszynski, I.: “VizieR Online Data Catalog: Magellanic clouds Cepheids JHKs photometry (Matsunaga+, 2011)”, 2019, VizieR Online Data Catalog, J/MNRAS/413/223.

Menzies, J.: “Long Period Variables in Local Group dwarf Irregular Galaxies”, 2019, IAU Symposium, 343, 472.

Meza, N., Prieto, J. L., Clocchiatti, A., et al.: “VizieR Online Data Catalog: Supernova ASASSN-14jb light curves and spectra (Meza+, 2019)”, 2019, VizieR Online Data Catalog, J/A+A/629/A57.

Mickaelian, A. M., Farmanyan, S. V., & Mikayelyan, G. A.: “IAU Regional Office of Astronomy for Development: Coordination in Southwest and Central Asia”, 2019, Astronomical Heritage of the Middle East, 520, 267.

Monageng, I., van der Horst, A. J., Woudt, P. A., Bottcher, M., & et al.: “GRB 190829A: MeerKAT radio observation”, 2019, GRB Coordinates Network, 25635, 1.

Otani, T., Oswalt, T. D., Lynas-Gray, A. E., et al.: “VizieR Online Data Catalog: 20yr obs. of the spectroscopic binary EC 20117-4014 (Otani+, 2018)”, 2019, VizieR Online Data Catalog, J/ApJ/859/145.

Pogrosheva, T., Lipunov, V., Buckley, D., et al.: “MASTER: new OT outburst and QSO flare”, 2019, The Astronomer’s Telegram, 12595, 1.

Pogrosheva, T., Lipunov, V., Gorbovskoy, E., et al.: “MASTER-SAAO: outburst with ampl>3.4m”, 2019, The Astronomer’s Telegram, 13294, 1.

Pogrosheva, T., Gress, O., Lipunov, V., et al.: “MASTER: new OT, ampl>4.5”, 2019, The Astronomer’s Telegram, 12473, 1.

Pogrosheva, T., Lipunov, V., Rebolo, R., et al.: “Master: Psn in PGC152821”, 2019, The Astronomer’s Telegram, 13091, 1.

Pogrosheva, T., Lipunov, V., Buckley, D., et al.: “MASTER-SAAO: very young SN in PGC087571”, 2019, The Astronomer’s Telegram, 13367, 1.

Pogrosheva, T., Lipunov, V., Buckley, D., et al.: “MASTER: new OT, ampl>4m”, 2019, The Astronomer’s Telegram, 12581, 1.

Pogrosheva, T., Lipunov, V., Buckley, D., et al.: “MASTER-SAAO: new OT with amplitude >4.6m”, 2019, The Astronomer’s Telegram, 12874, 1.

Pogrosheva, T., Lipunov, V., Rebolo, R., et al.: “MASTER: OTs detection”, 2019, The Astronomer’s Telegram, 12933, 1.

Pogrosheva, T., Lipunov, V., Buckley, D., et al.: “MASTER: 5.4mag amplitude optical transient”, 2019, The Astronomer’s Telegram, 12783, 1.

Pogrosheva, T., Lipunov, V., Gorbovskoy, E., et al.: “MASTER: QSO flare and OT outburst”, 2019, The Astronomer’s Telegram, 13311, 1.

Savinov, D., Shumkov, V., Lipunov, V., et al.: “MASTER: new OT, 6.5mag amplitude outburst”, 2019, The Astronomer’s Telegram, 12625, 1.

Strausbaugh, R., & Cucchiara, A.: “GRB 191004B: Continued Optical Afterglow Monitoring with LCO”, 2019, GRB Coordinates Network, 25977, 1.

Strausbaugh, R., & a larger collaboration: “GRB 191221B: LCO Optical Detection”, 2019, GRB Coordinates Network, 26560, 1.

Temple, L. Y., Hellier, C., Almleaky, Y., et al.: “VizieR Online Data Catalog: Radial velocity and light curves of WASP-190 (Temple+, 2019)”, 2019, VizieR Online Data Catalog, J/AJ/157/141.

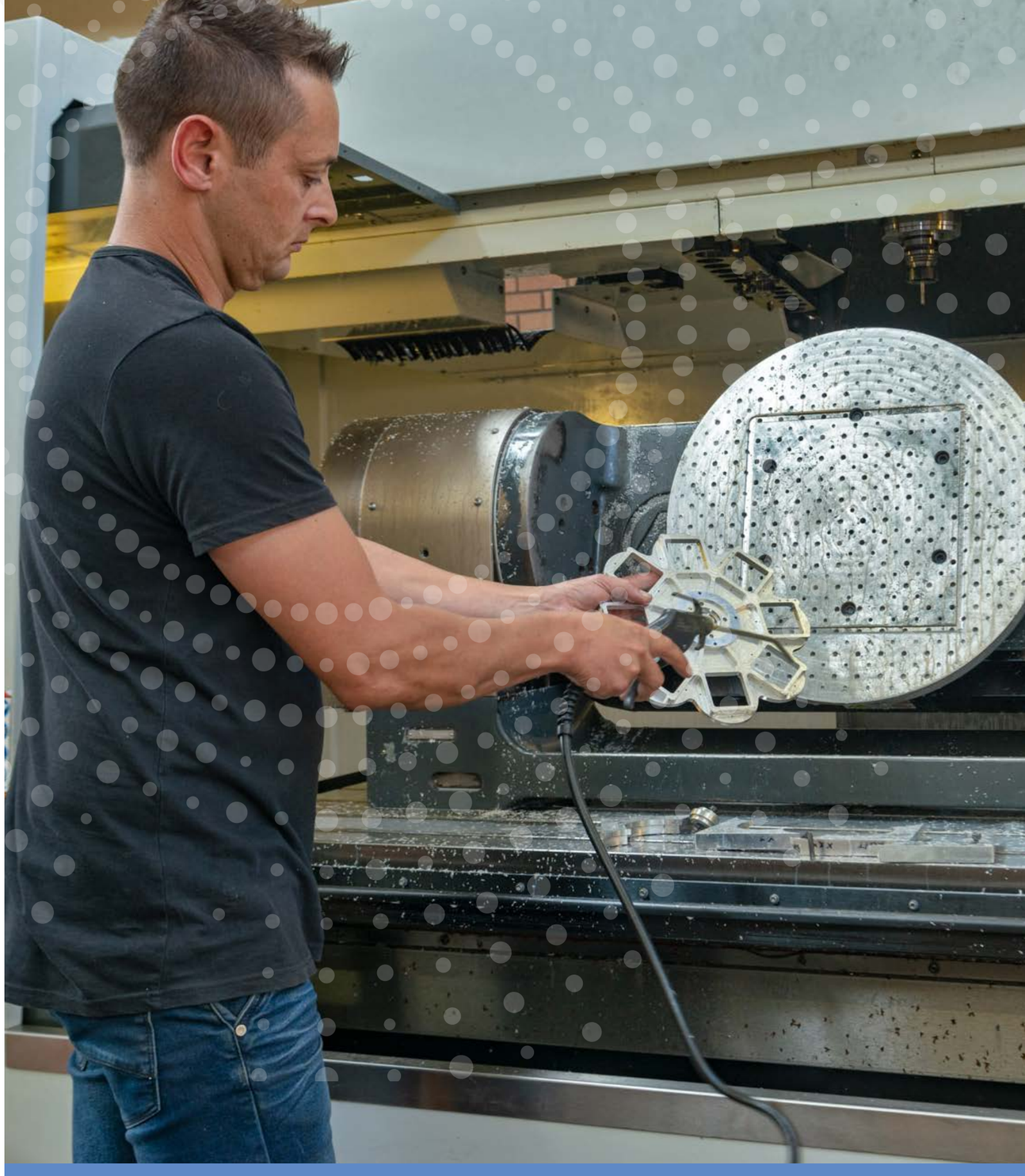
Thomas, J. K., Buckley, D. A. H., Kotze, E., & Potter, S.: “MAXI J1820+070: a new black hole low-mass X-ray binary candidate”, 2019, Mem. Societa Astronomica Italiana, 90, 103.

Vlasenko, D., Lipunov, V., Svinkin, D., et al.: “MASTER OT J080207.73+352847.7 discovery - optical afterglow of very bright GRB190530A”, 2019, The Astronomer’s Telegram, 12824, 1.

Von Schill, L., Fourie, A., & Kent, B. R.: “NRAO’s National and International Exchange Non-traditional Exchange (NINE) Program”, 2019, American Astronomical Society Meeting Abstracts #233, 233, 262.11.

You, S., Zhang, Q., Ma, L., Xu, M., & Lin, H.: “Treatment and Reuse of Black Water by Novel Energy-saving Shaft Anaerobic Anoxic Aerobic (S/A/A/O) System: A Novel Energy-saving Shaft Anaerobic Anoxic Aerobic (S/A/A/O) System for black water”, 2019, E3S Web of Conferences, 117, 00009.

Zhou, G., Bakos, G. A., Bayliss, D., et al.: “VizieR Online Data Catalog: Differential photometry & radial velocities of HATS-70 (Zhou+, 2019)”, 2019, VizieR Online Data Catalog, J/AJ/157/31.



SAAO STAFF

SAAO EXECUTIVE

In the reporting period of April 2019 to March 2020, the SAAO Executive comprised the following:

SAAO Executive Team

Mr Simon Fishley /
Mr Iriwaan Simon
Manager: Information & Technology

Mr Kevindran Govender
Director: IAU OAD

Mr Eugene Lakey
Manager: Finance and Operations

Mr Sivuyile Manxoyi
Manager: SALT Collateral Benefits Programme

Chris Coetzee /
Paul Rabe
Manager: SALT Tech Operations

Dr Stephen Potter
Head: Astronomy

Dr Encarni Romero Colmenero
Head: SALT Astronomy Operations

Dr Ramotholo Sefako
Head: Telescope Operations

Dr Amanda Sickafoose /
Mr Hitesh Gajjar
Head: Instrumentation

Mrs Linda Tobin
Manager: Human Resources

Prof. Petri Väisänen
Director: SAAO

STAFF LIST

This list includes casual staff, honorary fellows and students working at SAAO between April 2019 and March 2020.

Name	Title	Gender	Job Title	Location	
Alemu, Etsegenet	F	PhD Student		CT	
Anthony, Melissa	F	Procurement Officer		CT	
Appolis, Wade	M	CNC Mechinist		CT	
April, Koos	M	Driver/Maintenance		S	
Baadjies, Dawid	M	Driver/Maintenance		S	
Baadjies, Elizabeth	F	Receptionist		S	
Banda, Richard	M	Mechatronics Engineer		S	
Bassett, Bruce	M	Astronomer		CT	
Bernardo, Jean	M	IT Support Technician		CT/S	
Bershady, Matthew	M	SARChI Chair		CT	
Bichanga, Brian	M	Masters Student		CT	
Bok, Jamie	F	PhD Student		CT	
Bonokwane, Kelebogile	F	Masters Student		CT	
Booysen, Jacky	F	Cleaner		CT	
Booysen, Paul	M	IT Systems Administrator		S	
Botha, Lucian	M	Information Systems Specialist		CT	
Breytenbach, Hannes	M	PhD Student		CT	
Brink, Janus	M	Senior Software Engineer		CT	
Browne, Keith	M	SALT Electronics Engineer		S	
Buckley, David	M	Astronomer		CT	
Chattopadhyay, Sabyasachi	M	Post-Doctoral Fellow		CT	
Chingozha, Tawanda	M	OAD Fellow		CT	
Christian, Brendt	M	Mechanical Technician		CT	
Christians, Alrin	M	Mechanical-Design Draughtsman		S	
Claassen, Siphosethu	F	Human Resources Officer		CT	
Cloete, Valencia	F	Office & Grant Manager		CT	
Coetzee, Chris	M	SALT Technical Operations Manager		S	
Crause, Lisa	F	Astronomer/SALT Observatory Scientist		CT	
Cunnama, Daniel	M	Science Engagement Astronomer		CT	
Davé, Romeel	M	SARChI Chair		CT	
De Water, Katriena Wilhelmina	F	Housekeeper & Mirror Cleaner		S	
De Young, Theresa	F	Librarian		CT	
Depagne, Éric	M	SALT Astronomer		CT	
Dirkse, Andrew	M	Driver		CT	
Erasmus, Nicolas	M	Instrumentation Scientist		CT	
Feast, Michael	M	Astronomer		CT	
Fikelepi, Thabisa	F	Science Engagement Intern		CT	
Firth, Andrew	M	Masters Student		CT	
Fischer, Dalene	F	Financial Controller		CT	
Fourie, Chantal	F	IT Systems Administrator		CT	

Fourie, Pieter	M	Electronics Technician	CT	
Fransman, Timothy	M	Mechanical Technician	S	
Gajjar, Hitesh	M	Head of Instrumentation	CT	
Gelant, Fytjie Sylvia	F	Hostel Assistant	S	
Genade, Anja	F	PhD Student	CT	
Gibbons, Denville	M	Mechanical Assistant	S	
Gilbank, David	M	Astronomer	CT	
Glass, Ian	M	Astronomer	CT	
Govender, Kevindran	M	Director: IAU OAD	CT	
Govender, Pranesthan	M	Public Outreach Officer	S	
Groenewald, Daniel	F	SALT Astronomer	CT	
Harding, Jennifer	F	Cleaner	CT	
Hendricks, Johan	M	Driver/Maintenance	S	
Hendricks, Malcolm	M	CNC Programmer	CT	
Hettlage, Christian	M	SALT Software Engineer	CT	
Hewitt, Danté	M	Masters Student	CT	
Hlabathe, Michael	M	PhD Student	CT	
Hoosain, Munira	F	Masters Student	CT	
Hulme, Stephen	M	Software Engineer	CT	
Jacobs, Cedric	M	Education Assistant Officer	CT	
Jacobs, Nicolaas	M	Mechanical Assistant	CT	
Janse, Natalie	F	Cleaner	CT	
Jones, Natalie	F	Communications and Resources Officer	CT	
Kamfer, Hilton	M	Mechanical Technician	CT	
Kapank, Clint	M	Purchasing Officer	CT	
Karele, Sidney	M	Purchasing Officer	CT	
Kayyunnaparayil, Jessymol	F	Post-Doctoral Researcher	CT	
Khangale, Zwidofhelangani	M	PhD Student	CT	
Khumalo, Buzani	F	Education Officer	CT	
Klaaste, Petrus	M	Driver/Maintenance	S	
Klein, Francois	M	Tour Guide	S	
Klein, Reginald	M	Electronics Assistant	S	
Klein, Sina	F	Hostel Assistant	S	
Knyazev, Alexel	M	SALT Astronomer	CT	
Koen, Thea	F	SALT Telescope Operator	S	
Koeslag, Anthony	M	Software Engineer	CT	
Koorts, Willem	M	Electronics Technician	CT	
Kortje, Sofia	F	Hotel Assistant	S	
Kotze, Enrico	M	SALT Astronomer	CT	
Kotze, Marissa	F	SALT Astronomer	CT	
Kuhn, Rudolf	M	SALT Astronomer	CT	
Lakey, Eugene	M	Manager: Finance & Operations	CT	
Lande Cornelius	M	Finance Intern	CT	
Lombaard, Briehan	M	Web Developer	CT	
Loubser, Egan	M	Mechanical Technician	CT	

Love, Jonathan	M	Mechanical Technician	S	
Maartens, Deneys	M	Software Engineer	CT	
Macebele, Nhlavutelo	M	SALT Software Developer	CT	
Madhanpall, Nikhita	F	OAD Big Data Fellow	CT	
Maerman, Nkululeko	M	Machine Operator	CT	
Mahoro, Antoine	M	PhD Student	CT	
Makananise, Thabelo	M	Instrumentation Technician	CT	
Makda, Nazir	M	Masters Student	CT	
Malan, Adelaide	F	Administration Officer	S	
Mantungwa, Thembela	F	Communications Officer	CT	
Manxoyi, Sivuyile	M	Head of SALT Collateral Benefits Programme	CT	
Marang, Freddie	M	SALT Telescope Operator	S	
Mbatha, Phamela	F	SCM Intern	CT	
Mbetheni, Mitchell	M	Grounds Assistant	CT	
McBride, Vanessa	F	Astronomer	CT	
Menzies, John	M	Astronomer	CT	
Meswatu, Julie	M	Manager: Sutherland Site	S	
Mgwatyu, Ayanda	M	Site Supervisor	CT	
Mgwatyu, Sithembele	M	Groundsman	CT	
Mietas, Anthony	M	Manager: Collateral Benefits Sutherland	S	
Miller, Noel	M	Site Supervisor	CT	
Miszalski, Brent	M	SALT Astronomer	CT	
Mogawana, Orapeleng	M	Masters Student	CT	
Mogotsi, Moses	M	SALT Astronomer	CT	
Mohamed, Nazli	F	Personal Assistant Director	CT	
Mohamed, Shazrene	F	Astronomer	CT	
Monageng, Itumeleng	M	Post-Doctoral Fellow	CT	
Moosa, Surayda	F	SALT Accounts Clerk	CT	
Motsoaledi, Mokhine	F	PhD Student	CT	
Mputle, Ophemetse	M	Masters Student	CT	
Mulaudzi, Avhapfani	M	Electronics Technician	S	
Murphy, Geoff	M	Masters Student	CT	
Mvakade, Zuthobeke	F	Librarian Assistant	CT	
Myeza, Sifiso	M	SALT Software Developer	CT	
Nel, Sherelene	F	Hostel Assistant	S	
Ngxukumeshe, Livingstone	M	Grounds Assistant	CT	
Njadu, Gertruida	F	Hostel Assistant	S	
Nongca, Sive	F	Admin Assistant	CT	
Ntame, Masixole	M	Maintenance Assistant	S	
Ntozakhe, Mduduzi	M	Machine Operator	CT	
O'Connor, James	M	Mechanical Engineer	CT	
Paul, Bynish	M	PhD Student	CT	
Pieterse, Danielle	F	Masters Student	CT	
Potter, Stephen	M	Head of Astronomy	CT	
Pretorius, Retha	F	Instrument Scientist	CT	

Prins, Willem	M	Lead Maintenance Assistant	S	
Rabe, Paul	M	Head: SALT Operations	S	
Randriamanakoto, Zara	F	Post-Doctoral Fellow	CT	
Roode, Susan	F	Hostel Assistant	CT	
Rosie, Kathryn	F	Mechanical Engineer	CT	
Romero Colmenero, Encarni	F	Head of SALT Astronomy Operations	CT	
Rust, Michael	M	Electronics Technician	CT	
Saayman, Melanie	F	Optical Engineer	CT	
Sass, Craig	M	Head of Mechanical Workshop	CT	
Sangweni, Phumlani	M	Masters Student	CT	
Schröder, Anja	F	SALT PR Officer	CT	
Sefako, Ramotholo	M	Head of Small Telescope Operations	CT	
September, Juliana	F	SCPB Receptionist	S	
Sickafoose, Amanda	F	Head of Instrumentation	CT	
Simon, Etienne	M	Electronics Technician	S	
Simon, Iriwaan	M	Head of IT	CT	
Sisay, Melaku	M	Masters Student	CT	
Skelton, Rosalind	F	SALT Astronomer	CT	
Snowball, Glenda	F	Financial Officer	CT	
Sorgho, Amidou	F	OAD Fellow	CT	
Solomon, Nuhaah	F	OAD Administrative Officer	CT	
Southey, Grant	M	Procurement Officer	CT	
Stoffels, John	M	Mechanical Technician	S	
Strydom, Ockert	M	Engineering Specialist	CT	
Stuurman, Jeremy	M	SCBP Tour Guide	S	
Swanevelder, Pieter	M	Electronics Engineer	CT	
Taaibos, Sinethemba	M	All Sky Monitor Operator	S	
Thomas, Nicole	F	PhD Student	CT	
Titus, Keegan	M	Electronics Technician	CT	
Tobin, Linda	F	Manager: Human Resources	CT	
Väisänen, Petri	M	Director: SAAO	CT	
van Gend, Carel	M	Software Developer	CT	
van Jaarsveld, Naomi	F	PhD Student	CT	
van Wyk, Magdalena	F	Hostel Supervisor	S	
van Wyk, Patrick	M	Tour Guide	S	
van Wyk, Veronica	F	SALT Telescope Operator	S	
Venugopal, Ramasamy	M	OAD Fellow	CT	
Vernooi, Claudine	F	Tour Guide	S	
Visser, Martin	M	CNC Operator	CT	
Whitelock, Patricia	F	Astronomer	CT	
Wichman, Mark	M	SALT Software Engineer	S	
Wiid, Eben	M	Mechanical Technician	S	
Worters, Hannah	F	Astronomer	CT	
Yagob, Abubakr	M	Masters Student	A	
Zaula, Lonwabo	M	Software Intern	CT	
Zuma, Namisile	F	Library Intern	CT	

ACRONYMS

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 Officer
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
DSSI	Differential Speckle Survey Instrument
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
KMTNe	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
NHRA	National Heritage Resources Act
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

LIST OF ACRONYMS (cont.)

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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