ANNUAL REPORT 2023

SOUTHERN AFRICAN LARGE TELESCOPE


For 44km

External SALT review

An external review of SALT was conducted in 2023. It has been 12 years since the official start of operations and as such it was deemed useful to review how SALT operates and how it could be improved. The last SALT external review, held in 2016, was highly successful with the reviewers providing an excellent set of recommendations to strengthen the operations and governance of SALT. During the November 2021 SALT Board meeting, the Board agreed that 2023 would be a good time for a new external review.

The external review was held in the week of 16 – 20 October at SAAO in Cape Town. The panel consisted of:

Prof. Patrick Roche, Chair (University of Oxford, UK; President and delegate of ESO Council, Chair and member of the ALMA Board, member of the ESO and ALMA visiting committees, Chair of the AAT and the UKIRT Boards, and Chair and member of the ESO Scientific Technical Committee)

Prof. Nithaya Chetty (Vice-Chancellor of the University of Witwatersrand, South Africa, and well known to the SALT Board)

Prof. Gadiyara C. Anupama (Emeritus professor and ex-Dean at the Indian Institute of Astrophysics Bangalore, India; former Head of the Himalayan Chandra Telescope, President of the Astronomical Society of India)

Prof. Brian van Soelen (University of Free State, South Africa; a very active SALT user and previous Chair of the South African SALT Time Allocation Committee)

Their week was fully booked: Monday and Tuesday consisted of full-day meetings in Cape Town. On Wednesday the panel members travelled up to Sutherland and had the luck to witness a breathtaking wildflower display due to the recent heavy rains. Their time in Sutherland was likewise fully-booked with meetings with local staff. They returned to Cape Town on Thursday for the final day of intense meetings on Friday. On their last day they joined the traditional SAAO morning coffee at ten thirty in front of the SAAO main building.

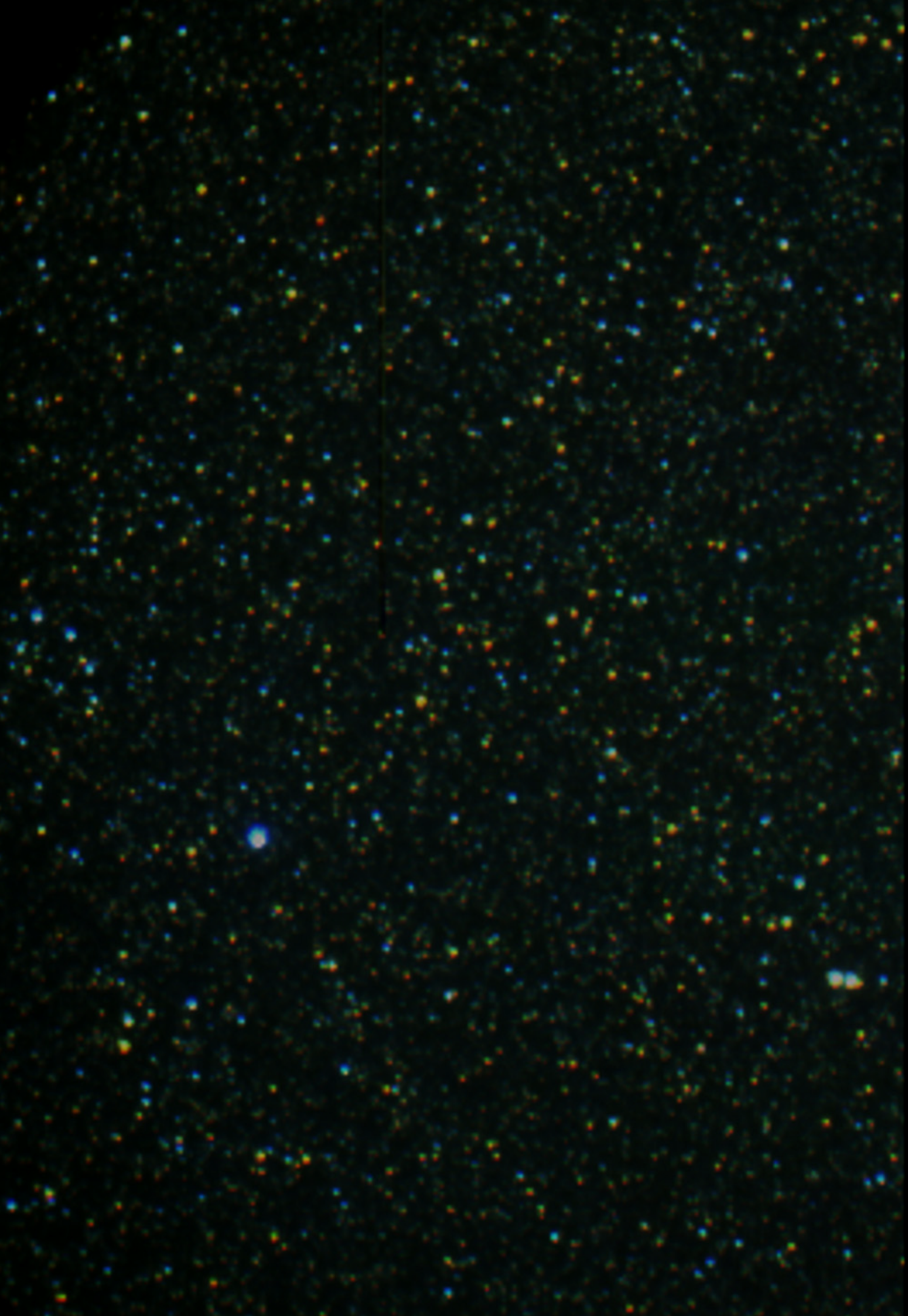
The report specifically noted and praised

- SALT's pivotal role in raising the profile of South African astronomy to its current prominent position on the world stage;
- SALT's production of good quality science with increasing numbers of journal papers and high impact results;
- The well-organised queue observations with rapid response times to targets of opportunity;
- The interactions between observers in the partnership and the astronomy operations staff.

One of the report's main recommendations was on the improvement of the management structure of SALT and its corporate governance. As a result, the SALT Board decided to create a new position, a SALT Director, who would report jointly to the SAAO managing director and to the SALT Board. The new SALT Director's main responsibility will be developing and leading the long term SALT strategic direction and goals and overseeing their implementation. The board is also reviewing its structure and operations to ensure they are following best practices in South Africa for corporate boards.

Other recommendations focused mainly on strategic improvements in operations, such as actively following up on various telescope metrics and benchmarking and ensuring that a proactive maintenance and resilience plan is in place as the telescope ages.

Photos inside front cover:
***Top*: The panel members are delighted by the beautiful display of the South African wild flower season.**
***Middle*: The panel members joining the SAAO morning coffee in front of the building.**
***Bottom*: The panel also had a tour of the Sutherland community centre while visiting SALT.**



SOUTHERN AFRICAN LARGE TELESCOPE

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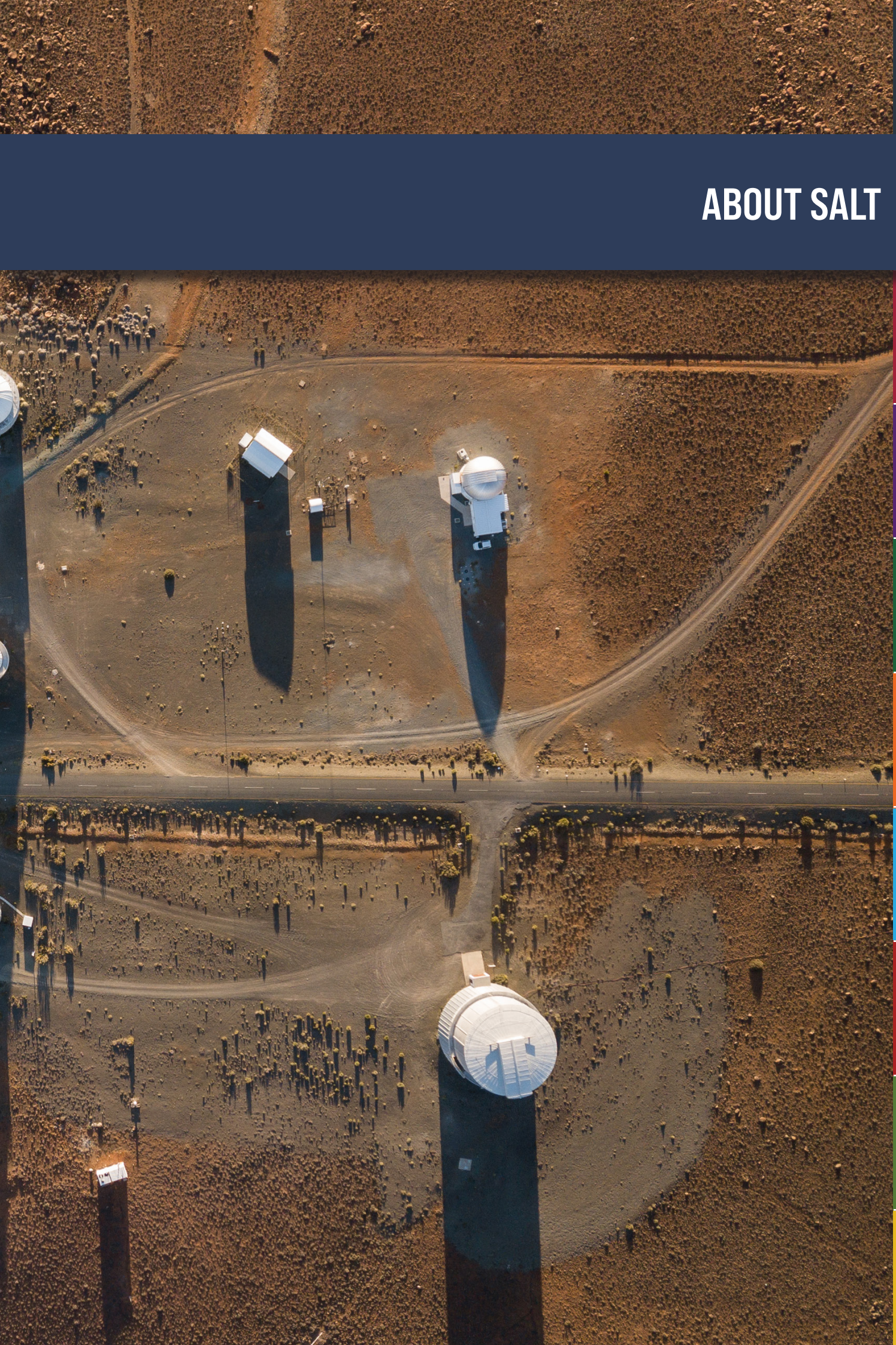


About SALT

SALT is the largest single optical telescope in the southern hemisphere and amongst the largest in the world. It has a hexagonal primary mirror array 11 metres in diameter, consisting of 91 individual 1-m hexagonal mirrors. It is the non-identical twin of the Hobby–Eberly Telescope (HET) located at McDonald Observatory in West Texas (USA). The light gathered by SALT's huge primary mirror is fed into a suite of instruments (an imager and three spectrographs) from which astronomers infer the properties of planets, stars and galaxies, as well as the structure of the Universe itself.

SALT is owned by the SALT Foundation, a private company registered in South Africa. The shareholders of this company include universities, institutions and science funding agencies from Africa, India, Europe and North America. The South African National Research Foundation (RSA) is the major shareholder with a ~52 percent stake. Other large shareholders are Rutgers University (RU), the Nicolaus Copernicus Astronomical Centre of the Polish Academy of Sciences (POL), Dartmouth College (DC), the University of Wisconsin–Madison (UW), and the Inter–University Centre for Astronomy and Astrophysics in India (IUCAA). Smaller shareholders include the American Museum of Natural History (AMNH) and the UK SALT Consortium (UKSC), with the latter representing the Universities of Central Lancashire, Keele, Southampton, the Open University and the Armagh Observatory. The size of the shareholding of each partner determines the access to the telescope that they enjoy. The HET Consortium, although not a shareholder, received ten percent of the telescope time for the first ten years of operation, in return for providing all of the designs and plans from the HET, as well as assistance during the construction of SALT. Three of the original shareholders, Göttingen University (GU), the University of Canterbury (UCN) and the University of North Carolina (UNC), as well as the University of Nottingham of the UKSC, left the SALT Foundation. The SALT Foundation is currently looking for new shareholders.

SALT is located at the observing site of the South African Astronomical Observatory (SAAO), near the small Karoo town of Sutherland, about 370 km northeast of Cape Town. This site has been host to a number of other smaller telescopes since the early 1970s, and benefits from its location in a semi-desert region with clear, dark skies. The quality of this site for optical astronomy is preserved by South African legislation.

Vision

Africa's Giant Eye on the Sky: Inspiring society by exploring the Universe.

Mission

Lead the advancement and development of optical astronomy on the African continent and inspire and educate new generations of scientists and engineers worldwide.

Provide a world-class large telescope research facility cost-effectively to astronomers in an international community.

Strategic Objectives of SALT

1 Enable world-leading astrophysical research

To provide high-quality data that result in highly-cited papers published in front-rank journals. This is achieved by maximising SALT's scientific productivity, i.e., minimising technical downtime and optimising operational efficiency. Which is contingent on having the financial resources to support operational needs and to nurture and retain a cohort of skilled and creative staff, and enabling them to identify and pursue key scientific and technical initiatives.

2 Pursue instrumentation development

To establish the local skills and capacity required to design and build internationally competitive astronomical instrumentation. This calls for leveraging expertise available within the SALT partnership and other international instrumentation groups, to build active collaborations that drive technological innovation and skills transfer, and ultimately enhance SALT's capabilities. This, too, relies on securing the necessary financial support, for both equipment and people (staff, students, interns and apprentices spanning a broad range of levels).

3 Drive human capital development and science engagement

To employ this iconic facility and the ubiquitous appeal of astronomy to encourage widespread interest in science and technology, through outreach to undergraduates, schools and the general public; to train graduate students; to have a special focus on developing and leading professional astronomy and high-tech astronomical instrumentation on the African continent; to promote SALT as a global flagship optical telescope, increasing its visibility and growing its reputation in the international scientific community, as well as national and international media.

The Board of the Southern African Large Telescope (SALT) is proud to present its Annual Performance Report for the period 1 January 2023 to 31 December 2023. This report offers an overview of the activities and performance of SALT, highlights a selection of SALT research projects, and introduces the SALT partner institutions/consortia.

CHAIRMAN'S OVERVIEW

The year 2023 has shown some considerable progress in the SALT instrumentation projects. The new instrument NIRWALS is already available for shared-risk observation, and one of the new slitmask IFUs for RSS-VIS has been assembled, integrated and thoroughly checked in the laboratory environment.

In 2020 the SALT Board decided on a short-term upgrade project for the RSS, dubbed 'The Big 5'. Of these, three have been completed, that is, the new PG0700 grating in 2022 and the new collimator doublet and the triplet this year. And the good news is that the troublesome RSS scattered light has disappeared! On the new long-slits we can also report good news: the SAAO mechanical workshop is cutting high-quality slits, which are currently being tested. They should become available soon. That leaves the new RSS detector, which is closely tied in with the planned RSS Red arm (aka MaxE). Here, a fruitful collaboration with IUCAA is helping to advance the project.

Considerable progress has also been made in the development of the laser frequency comb for the HRS. Project leader Richard McCracken from Heriot-Watt University in Edinburgh, UK, and his colleagues have travelled to South Africa a couple of times for assembly and integration. This will continue in 2024 and, hopefully, first light will be coming up towards the end of the year.

Another good news is the upgrade of the seeing monitor system, TimDIMM. While it was not possible to quite finish the upgrade in 2023, the new system will be available in the next few months.

On the publication front, we had a low-production year with 47 refereed publications, which is still good in a statistical sense. It is likely that we are facing the drop in productivity in the year 2020, which was strongly affected by the COVID-19 pandemic. Furthermore, there are quite a number of papers 'in the pipeline' as reflected by the 24 papers published uniquely on arXiv by the end of 2023.

Another highlight of 2023 was the external review meeting held in October. It was highly successful with many good recommendations. We are grateful for the review panel members Patrick Roche (Chair; University of Oxford, UK), Nithaya Chetty (Dean of Science, University of Witwatersrand, South Africa), G.C. Anupama (Indian Institute of Astrophysics Bangalore, India) and Brian van Soelen (University of Free State, South Africa). The committee spent an intense week visiting SALT and SAAO. The report praised the scientific productivity of the observatory, and highlighted the well regarded queue observations with rapid response times to targets of opportunity. The recommendations from the committee focused on improving the management structure of SALT and its corporate governance. As a result of these recommendations, the SALT board agreed to hire a SALT Observatory Directory, who would report jointly to the SAAO managing director and the SALT Board. The new Observatory Directory will be solely focused on SALT operations and developments. The hiring process for this new position is underway, and it is anticipated that a SALT Observatory Director will be named in 2024. The board is also reviewing its structure and operations to ensure we are following best practices in South Africa for corporate boards.

Outreach activities have also picked up again after the COVID-19 restrictions have been lifted. Our public interaction numbers are back to normal, with some exciting new projects being initiated or continued. SAAO and SALT were pleased to host a contingent of 22 students and faculty from Dartmouth College for a ten-week period starting in January. During this period the Dartmouth group participated in a number of outreach activities to schools in Cape Town and Sutherland.

The SALT board continues to be grateful for the excellent work being done by SALT staff. SALT operates on a relatively lean budget, and is able to do so due to the focus and dedication of the SALT astronomy and operations teams.

Prof. Brian Chaboyer
Chairperson, SALT Board

SALT PARTNERS

Introduction

SALT is an international consortium consisting of a number of partners that share the costs of the telescope, in return for corresponding fractions of the available observing time. Some of the partners have also made in-kind contributions, in the form of instruments and/or other intellectual property, to secure their membership. Each partner country or institution has their own time allocation committee, and scientists outside the consortium that wish to use SALT are welcome to collaborate with those affiliated with partner institutions. SALT also offers a limited amount of free Director's Discretionary Time* (DDT) for the opportunistic pursuit of high-impact science, as the flexibility of SALT's queue-scheduled operation supports the rapid response to new top-priority targets.

The SALT Foundation now also invites researchers from around the world to purchase their own guaranteed SALT time. This can be in the form of normal time divided into the default priority categories ("P0" to "P3"), to be inserted in the service observing (at a rate of ~$2400/h). It may also be in the form of the highest priority time only, which is guaranteed to be observed fully, at a rate of ~$3200/h. Note that any partner institution may also purchase time beyond their normal share, and reduced rates apply in that case. Finally, the consortium is seeking an additional 10%-level partner (~$10.5M) to support significant second-generation instrumentation development. Interested parties should contact the chair of the SALT Board of Directors, Brian Chaboyer.

* *https://astronomers.salt.ac.za/proposals/directors-discretionary-time/*

Republic of South Africa

South Africa's National Research Foundation (NRF) is the majority shareholder in SALT, with approximately a one-half share. The South African Astronomical Observatory (SAAO), contracted to host and operate SALT, is also one of the NRF's several national facilities. As the intermediary agency between the policies and strategies of the government of South Africa and the country's research institutions, the NRF's mandate is to promote and support research through funding, human resource development and the provision of the necessary facilities, in order to facilitate the creation of knowledge, innovation and development in all fields of science and technology (including indigenous knowledge), and to thereby contribute to improving the quality of life of all South Africans. The country's considerable investment in astronomy, both in optical and radio, is due in no small part to this field's extraordinary potential to capture the imagination and hence to encourage the brightest young minds to pursue scientific and technical qualifications.

SALT is located at the Sutherland site of the SAAO in the Karoo desert (about 370 km from Cape Town), making it one of the darkest observing sites in the world. SAAO hosts all the SALT Astronomers, responsible for liaising with PIs and making the observations, as well as all the technical and support staff associated with SALT. The Observatory's mechanical and electronics departments at the SAAO headquarters in Cape Town include large workshops and a dedicated CCD lab. SALTICAM and the RSS detector packages, as well as the fibre-instrument feed and various auto-guiders for the SALT instruments, were designed and built here. The maintenance and servicing of all instruments and telescope sub-systems are done in Sutherland by the Technical Operations team.

One of SALT's strategic objectives is Human Capital Development which is particularly important for South Africa and, even more so, for the African continent. Thus the SALT Collateral Benefits Programme (SCBP) was established during the construction of SALT and the objectives of this programme were clearly directed at the benefits derived by society from building this large telescope. The SCBP is mainly directed at schools but also includes outreach to the general public.

South Africa's astronomical community has grown significantly since SALT was built, with SALT and later the MeerKAT initiatives spurring much of this growth. The entire South African community has access to SALT. There are now over two hundred PhD astronomers, and students are encouraged to participate in SALT projects and to propose for time. The recent decision to have two additional board members from South Africa will provide further opportunities to develop leadership expertise and to continue to drive optical astronomy research. Towards the end of the year, board member V. McBride resigned and took up a new position elsewhere. Her position has not been filled yet.

South African researchers are active across a wide range of the multi-wavelength astronomy domain. The strategic vision for SALT, developed by the South African community in 2017, identified two main focus areas for future development, which tie in closely with both MeerKAT, the country's precursor to the SKA, and local high-energy astrophysics research. These are transient science and galaxy evolution (particularly understanding the fuelling of star formation and recycling of gas in the baryon cycle). Exoplanet research and building instrumentation capacity have also been highlighted as growth points for the future, resulting in the current improvements of the high-stability mode of the HRS.

SALT Board members:
Vanessa McBride, SAAO/OAD
Fulufhelo Nelwamondo, NRF
Sharmila Goedhart, SARAO
Itumeleng Monageng, SAAO/UCT

Rutgers University (USA)

Rutgers, the State University of New Jersey, is a large public research university in the United States. Originally chartered as Queen's College in 1766 during the colonial era, in 1825 it was renamed Rutgers College after a wealthy benefactor. Rutgers became the New Jersey land-grant institution in 1864 and in the mid-20th century, it was designated the State University of New Jersey by the state legislature. Rutgers University has expanded far beyond its modest colonial roots and now includes campuses in Newark and Camden as well as the flagship campus in New Brunswick. Across the state, more than 8000 Rutgers faculty instruct over 49,000 undergraduate as well as 19,000 graduate students. There are more than 150 undergraduate majors and 200 graduate programs.

Astronomy was part of the curriculum at Rutgers since its earliest days. The current Department of Physics and Astronomy at Rutgers–New Brunswick traces its origins to the late 19th century. Significant expansion in the astronomy programme began in the 1990s with the addition of a number of research-active astronomers and an increase in the number of graduate students. In 2001, Rutgers joined the SALT consortium. The astronomy group in 2023 comprised eight faculty, four emeritus faculty, five postdoctoral associates (including one LSSTC Catalyst Fellow and two joint Rutgers-Flatiron Postdoctoral Fellows), and 26 graduate students. A record number of five Rutgers astrophysics graduate students defended their PhD theses in 2023, three of whom worked with SALT observations.

Rutgers hosted UCT student Munira Hoosain for two months under the SALT Scholarships and Visits programme. She worked with A. Baker and E. Gawiser on a project on the cosmic density of H I at intermediate redshifts. The visit was highly successful in terms of Munira making progress on multiple research fronts, enhancing her own career through networking and experiencing graduate student life in another country, and in strengthening collaboration between Baker, Gawiser and Munira's UCT/SAAO supervisors, S. Blyth and R. Skelton.

Rutgers' astronomers, led by T. Williams, participated in the design, development and fabrication of the RSS and led the effort to build the Fabry–Pérot (FP) Imaging Spectrophotometer subsystem. Williams and his colleagues used this instrument to carry out the RSS Imaging spectroscopy Nearby Galaxies Survey (RINGS) of nearby, normal galaxies to characterise their structure using measurements of Hα velocity fields.

S. Jha uses SALT/RSS to study supernova (SN) explosions, observing mostly type Ia SNe to investigate their nature and, more broadly, to answer key questions in SN Ia cosmology. Jha has been measuring binary orbital parameters of a sample of candidate white dwarf binaries with the HRS and has used RSS spectroscopy to observe a sample of *Gaia* hypervelocity stars.

The main focus of J.P. Hughes' current research is the astrophysics of supernova remnants and clusters of galaxies. Two graduate students working with him, P. Doze (studying clusters) and P. Arunachalam (studying remnants), were awarded their PhD degrees in 2023 based partially on work done with SALT. In collaboration with colleagues in South Africa, Hughes is studying the brightest cluster galaxies in massive clusters detected by the AdvACT. The goal is to trace the evolution of AGN feedback (both radio and quasar mode), stellar populations, and the growth of central galaxies in clusters over a 3.4 Gyr time period ($0.3 < z < 0.8$). Hughes also has an on-going SALT project for confirmation and redshift measurement of Planck cluster candidates.

A. Baker is involved in two large SALT collaborations: the "SALT Gravitational Lensing Legacy Survey" targets sub-mm-band sources from the Herschel space mission that are likely high-redshift ($z \sim 2 – 4$), gravitationally-lensed star-forming galaxies. The second project, "Preparing for LADUMA: SALT Redshift Measurements", aims at obtaining redshifts of galaxies in the LADUMA field to allow stacking of 21-cm H I spectra. Baker is Co-PI of the LADUMA radio survey with the South African MeerKAT array to study the evolution of neutral gas in galaxies over cosmic time.

E. Gawiser is working with a group of undergraduate students to observe low redshift ($z < 0.4$) [O II]-emitting galaxies from HETDEX, thereby revealing key properties of these star-forming galaxies.

SALT Board member:
Jack Hughes

Photo:
The Physics & Astronomy department building at Rutgers–New Brunswick.

Poland

Poland is a country with a long astronomical tradition. For example, Nicolaus Copernicus (1473–1543) was the creator of the heliocentric system, and Johannes Hevelius (1611–1687) was the founder of lunar topography. After World War II, Polish astronomy started to slowly build up its resources but it was only after the communist regime fell in 1989 that Poland could join ESO, ESA and other international astronomical organisations. About 250 astronomers are employed at six separate universities and two institutes of the Polish Academy of Sciences (PAS). Some of these form the Polish SALT Foundation, which has a 10% share in the construction and running costs of SALT. There are five main SALT partner institutions.

The **Nicolaus Copernicus Astronomical Center** (CAMK, or NCAC in English) of the PAS is the leading astronomical institute in Poland. It is located in Warsaw and was established in 1978. It is the coordinator of the SALT project, with K. Hełminiak being Poland's Board director since November 2023. The former representative, M. Sarna, had been highly active in the Board and other SALT committees since 2000. J. Mikołajewska is a member of the STC, being highly involved in several SALT committees. At present, 80 scientists are working at CAMK along with ~30 PhD students. They are involved in a number of major international observational projects (*e.g.*, CTA, *Athena*, SALT, LIGO-VIRGO, BRITE, PLATO, Ariel), and collaborate with scientists all over the world. Scientific research conducted at CAMK with SALT include: the search for symbiotic stars and the study of individual systems; classical and recurrent novae; post AGB binaries; multiple stellar systems; characterisation of exoplanet host stars; dark matter studies using spectroscopic long term monitoring of selected quasars.

The **Astronomical Observatory of the Jagiellonian University** is a part of the Faculty of Physics, Astronomy and Applied Computer Science of the Jagiellonian University. The Observatory was founded in 1792 and comprises a number of small radio and optical telescopes that are located at Fort Skała on the outskirts of Kraków. The Observatory is involved in exploiting large facilities such as H.E.S.S., CTA and SALT and runs one of the LOFAR telescope stations. SALT data is used in studies of giant-size radio galaxies, accretion discs in AGNs using Doppler tomography and timing analysis of their multi-wavelength light curves.

The **Institute of Astronomy of the Nicolaus Copernicus University** in Toruń, located in Piwnice village, 15 km north of Toruń, is home to a VLBI station and a few optical instruments. The telescopes are used mainly for student training and modest research projects. SALT researchers are interested in symbiotic stars and novae as well as PNe.

Founded in 1919, the **Institute Astronomical Observatory** (IAO) of Adam Mickiewicz University runs a Global Astrophysical Telescope System (GATS) consisting of two robotic instruments (Poland and Arizona) used for photometry and spectroscopy. The third node — a cluster of 0.7-m and 0.3-m telescopes for space debris tracking — is under construction. IAO uses SALT for photometric and spectroscopic observations of asteroids.

The **Astronomical Institute of the Wrocław University** is located in the eastern part of Wrocław. Research concentrates on the investigation of solar activity (with a coronagraph located near Wrocław) and on pulsating stars (with SALT among others). Satellite observations also play an important role in these investigations.

CAMK PAN

ASTRONOMICAL OBSERVATORY Adam Mickiewicz University POZNAŃ

Uniwersytet Wrocławski Instytut Astronomiczny

OBSERWATORIUM ASTRONOMICZNE UNIWERSYTETU JAGIELLOŃSKIEGO

NICOLAUS COPERNICUS UNIVERSITY IN TORUŃ

SALT Board member:
Krzysztof Hełminiak, CAMK

Photo:
The Nicolaus Copernicus Astronomical Center in Warsaw.

Dartmouth College (USA)

Founded in 1769, Dartmouth College is one of the leading liberal arts universities in the United States. Dartmouth has forged a singular identity for combining its deep commitment to outstanding undergraduate liberal arts and graduate education with distinguished research and scholarship in the Arts & Sciences, and its three leading professional schools: the Geisel School of Medicine, the Thayer School of Engineering, and the Tuck School of Business. Dartmouth College educates the most promising students (approximately 4300 undergraduates and 2000 graduate students) and prepares them for a lifetime of learning and of responsible leadership, through a faculty dedicated to teaching and the creation of knowledge.

Astronomy has a long history at Dartmouth, with the Shattuck Observatory (built in 1853) being the oldest scientific building on campus. The first photograph of a solar prominence was obtained by the Shattuck Observatory (in 1870).

Today, the astronomy group at Dartmouth is housed within the Department of Physics and Astronomy and has a 25% share in the MDM observatory (consisting of a 2.4-m and 1.3-m telescope in Kitt Peak, Arizona, USA) in addition to its ~10% investment in SALT. Astronomers at Dartmouth have a broad range of research interests and have used SALT to study supernovae, active galactic nuclei and metal-poor stars, among other projects. Currently, the astronomy group consists of six faculty members, two post-doctoral fellows and about ten graduate students.

SALT Board member (chair):
Brian Chaboyer

Photo:
The Shattuck Observatory on campus.

University of Wisconsin–Madison (USA)

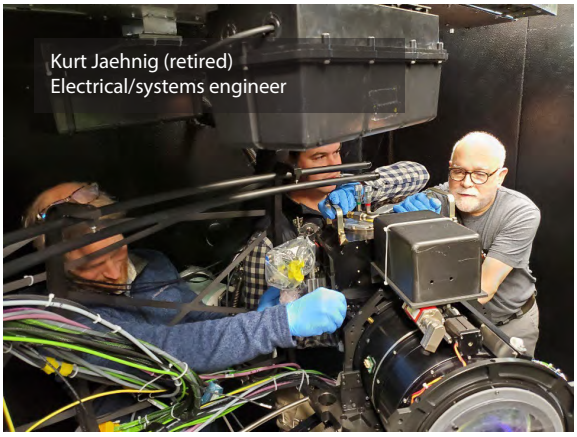
The University of Wisconsin–Madison is a public, land-grant institution that offers a complete spectrum of studies through 13 schools and colleges. With more than 43,000 students from every U.S. state and 121 countries, UW–Madison is the flagship campus of Wisconsin's state university system.

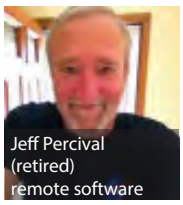
UW–Madison is a formidable research engine, ranking sixth among U.S. universities as measured by dollars spent on research. Faculty, staff, and students are motivated by a tradition known as the Wisconsin Idea that the boundaries of the university are the boundaries of the state and beyond.

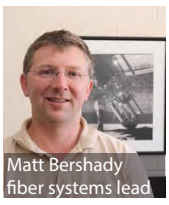
One of two doctorate-granting universities in the University of Wisconsin System, UW–Madison has the specific mission of providing "a learning environment in which faculty, staff and students can discover, examine critically, preserve and transmit the knowledge, wisdom and values that will help ensure the survival of this and future generations and improve the quality of life for all."

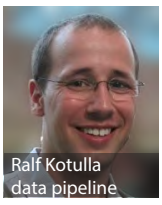
UW–Madison joined the SALT partnership, contributing both to the construction as well as designing and building the Prime Focus Imaging Spectrograph since renamed the Robert Stobie Spectrograph (RSS). Washburn Labs recently completed and delivered a near-infrared, integral-field spectrograph for SALT, called NIRWALS. The Washburn Labs team is working with SALT engineers and astronomers to commission the instrument for use in 2024. UW–Madison plans to undertake large surveys with this new facility instrument.

Wisconsin astronomers have traditionally used SALT to understand the kinematics and distribution of ionised gas in and around galaxies, the stellar content and dynamics of nearby galaxy discs, as well as for redshift surveys to measure the distribution of mass in galaxy clusters. Recently, there is increasing interest in high-resolution spectroscopy of multiple stellar systems. With the rapid growth in recent years of a now-large, inter-disciplinary exoplanet group across departments in Astronomy, Chemistry, Physics, and Atmospheric Sciences, there is an anticipated high demand for high-stability spectroscopy for identification and characterisation of exoplanet systems.









SALT Board member:
Matthew Bershady

Photo:
The NIRWALS commissioning team.

Inter-University Centre for Astronomy & Astrophysics (India)

The Inter-University Centre for Astronomy & Astrophysics (IUCAA) was established in 1988 by the University Grants Commission of India in Pune. The main objectives of IUCAA are to provide a centre of excellence within the university sector for teaching, research and development in astronomy and astrophysics, as well as to promote nucleation and growth of active groups in these areas in colleges and universities. Besides conducting a vigorous research programme of its own, workers from Indian universities, teachers and students are enabled to visit IUCAA for any length of time to participate in research and to execute developmental projects. IUCAA also actively collaborates with universities in initiating and strengthening teaching and research in Astronomy & Astrophysics in the university system.

Research interests of IUCAA members and associates include (i) gravitation, cosmology, large scale structures in the Universe, gravitational wave physics and data analysis; (ii) cosmic microwave background theory and data analysis, cosmic magnetic fields; (iii) galaxies, quasars, quasar absorption lines, intergalactic and interstellar matter; (iv) X-ray binaries, accretion disc theory, radio and X-ray pulsars, gamma-ray bursts; (v) solar physics, stellar physics, stellar spectral libraries, machine learning; (vi) observations in optical, radio and X-ray bands, astronomical instrumentation and (viii) data-driven astronomy, virtual observatory. IUCAA runs a 2-m telescope at Girawali to support various observational projects. Members of IUCAA are actively involved in various national large science projects such as the Indian participation in TMT, SKA and LIGO–INDIA etc., and IUCAA has a 7% share in SALT. It is used to identify and study extragalactic sources (large scale outflow, quasars, radio galaxies and field galaxies producing absorption lines in quasar spectra), high-resolution spectroscopy of stars and coordinated observations of time-varying sources. Astronomers from IUCAA are also involved in various Indian space observatories like Astrosat and Adithya-L1.

IUCAA's technical contribution to SALT is the SIDECAR Drive Electronics Controller (ISDEC) which is used as the control and data acquisition system for the H2RG detector in the new NIRWALS spectrograph.

SALT Board member:
Raghunathan Srianand

Photo:
View of IUCAA's campus.

UK SALT Consortium

An early and enthusiastic supporter of the SALT project, the UK's consortium (UKSC) originally consisted of six astronomy groups, reducing to five with the exit of Nottingham following a retirement. All of UKSC have had a long-standing involvement with astronomers in South Africa (SA), including providing support for visiting graduate students and postdocs to SA. UKSC has successfully hosted a half-dozen SALT–Stobie scholarships, greatly enhancing the production of SA astronomy PhDs. From 2018 – 2020, the "Global Challenges" research funding was used to support SA post-docs to visit the UK for extended periods, and follow-up visits have continued. UKSC have a wide range of SALT science interests and are involved as collaborators in a number of major SALT science projects, in particular playing a leading role in the X-ray binaries component of the SALT Transients Large Programme. The following institutions form the UKSC.

SALT scientists at the **University of Central Lancashire** (UCLan) include G. Bromage, A. Sansom, D. Kurtz and D. Holdsworth. Bromage was UKSC's previous Board director and has been active in other SALT committees, currently as a member of FAC. UCLan has made extensive contributions to the SCBP, has hosted successful SALT–Stobie scholarships, has provided UCLan's distance learning university-level Astronomy courses (at discounted rates) for SALT staff, and is supporting visiting graduate students. SALT science interests involve collaborations within UKSC (with Keele and Armagh) and with SA (mostly with NWU and SAAO).

At the **Open University**, science interests range from the "Dispersed Matter Planet Project" (C. Haswell), which has identified a key population of rocky exoplanets orbiting bright nearby stars and catastrophically disintegrating planets, to studies of variable star populations and unique individual variables from SuperWASP (A. Norton, M. Lohr). Norton has recently focussed on close-contact red giant eclipsing binary candidates which may be red nova progenitors. S. Serjeant, S. Urquhart (who takes over as UKSC Board director for SALT from 2024) and L. Marchetti (UCT) coordinate the "SALT Gravitational Lensing Legacy Program", which combines *Herschel* wide-area sub-mm observations with multi-wavelength ancillary data to generate the largest (> 500) sample to date of homogeneously selected lens candidates, obtaining SALT spectroscopy for most of them. These data will be used in conjunction with Urquhart's recent results, the Bright Extragalactic ALMA Redshift Survey (BEARS), identifying redshifts of bright gravitationally-lensed galaxies from the *Herschel* ATLAS.

SALT science at **Armagh Observatory & Planetarium** focuses on stellar remnants, massive stars, ultra-compact binary systems, and solar-system science, with extensive effort on stellar pulsations and abundance analyses using SALT's RSS and HRS, with collaborations within UKSC and with SA (SAAO, UCT and UWC). People involved at Armagh are S. Jeffery, M. Burton, G. Ramsay, J. Vink, G. Doyle as well as M. Sarzi, who has taken on the role of representing Armagh on UKSC. AOP is now the UKSC administrating institution.

At **Keele University**, J. van Loon's interests in SALT have been to exploit the RSS-FP mode to map emission as well as absorption features in nearby galaxies, and long-slit spectroscopy of various types of stars but mostly a series of AGN. This work is generally done as part of PhD projects including students from underprivileged countries. It has featured in press releases and in a science-art outreach project at Sutherland's High School.

P. Charles from the **University of Southampton** (UKSC Board director for SALT from 2015 to 2024) was SAAO Director for seven years (2004 – 2011) and, together with many of the Southampton Astronomy Group, is actively involved in the SA-led SALT-LSP "Observing the Transient Universe". Southampton's interests focus on black-hole, neutron star and white dwarf X-ray binaries, usually in association with other ground-based (*e.g.*, ASASSN, OGLE, MASTER) and space-based (*e.g.*, *Swift*, *MAXI*, *Astrosat*) facilities, frequently arranging for simultaneous or contemporaneous observing. M. Sullivan is involved in SN–cosmology studies, which is part of the SALT long-term programme on supernovae. SALT is also used for rapid follow-up spectroscopy of outbursting X-ray sources in the SMC arising from the ongoing *Swift*'s S–CUBED monitoring (M. Coe). Also interested in SALT science are C. Knigge, D. Altamirano, T. Bird, P. Gandhi and M. Middleton.

SALT Board member:
Phil Charles, University of Southampton

Photo:
The photo was taken at the UKSC management committee meeting in Keele in November 2017.

The American Museum of Natural History (USA)

The American Museum of Natural History (AMNH) is one of the world's preeminent scientific and cultural institutions. Since its founding in 1869, the Museum has advanced its global mission to discover, interpret, and disseminate information about human cultures, the natural world, and the Universe through a wide-ranging programme of scientific research, education, and exhibition. With 200 active researchers, including curator/professors, postdoctoral fellows, PhD and Masters degree students as well as research associates and assistants, AMNH is the only institution in North America that is both a research university and a museum, hosting over five million visitors each year.

Astronomy has been part of AMNH since the opening of the Hayden Planetarium, partly funded by philanthropist Charles Hayden, in 1934. The completely rebuilt Planetarium, opened in 1999, is a 30-m diameter sphere inside an eight story-high glass cube, which houses the Star Theater. The theatre uses high-resolution full-dome video to project space shows based on scientific visualisation of current astrophysical data. A customised Zeiss Star Projector system replicates an accurate night sky as seen from Earth. The AMNH Astrophysics research department is responsible for the content of space shows, for conducting research in astrophysics, and for training graduate students and postdoctoral fellows.

AMNH became a member of SALT in 2008 on the basis of a gift from the late Paul Newman. AMNH astrophysicist Michael Shara became Chairman of the SALT Board in 2012 and served in that position until 2021. Shara uses SALT to study cataclysmic binary stars — novae, the stars that give rise to them, and the ways that they hide from astronomers during the millennia between eruptions. He is also interested in mass transfer in such binaries that spins up the black hole progenitors — O stars in O+Wolf-Rayet star binaries — to high speeds.

In collaboration with Shara, PhD student Laura Rogers (University of Cambridge) continues to use SALT/HRS to characterise white dwarfs heavily polluted with metals, probably via accretion of asteroids and dust. AMNH Postdoctoral Fellow Sam Grunblatt has initiated an HRS study of hot, southern exoplanet candidates identified with *TESS*. The first radial velocity detection of a planetary orbit with SALT/HRS was published in 2022; follow-up observations will be used to confirm a second planetary signal from this survey. J. Faherty is interested in brown dwarfs and has recently obtained SALT spectroscopy on objects newly identified in a citizen science project.

SALT Board member:
Michael Shara

Photo:
The American Museum of Natural History's Rose Center for Earth and Space in New York City.

SCIENCE HIGHLIGHTS

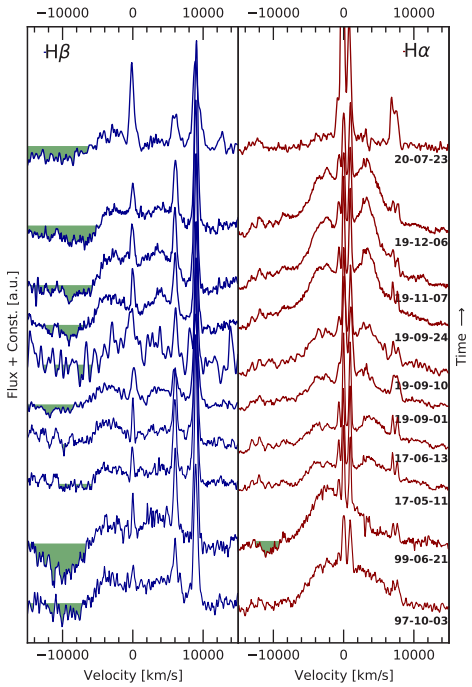
SCIENCE HIGHLIGHTS:
Extragalactic astronomy

SALT witnesses the 2019 outburst of the changing-look AGN IRAS 23226–3843

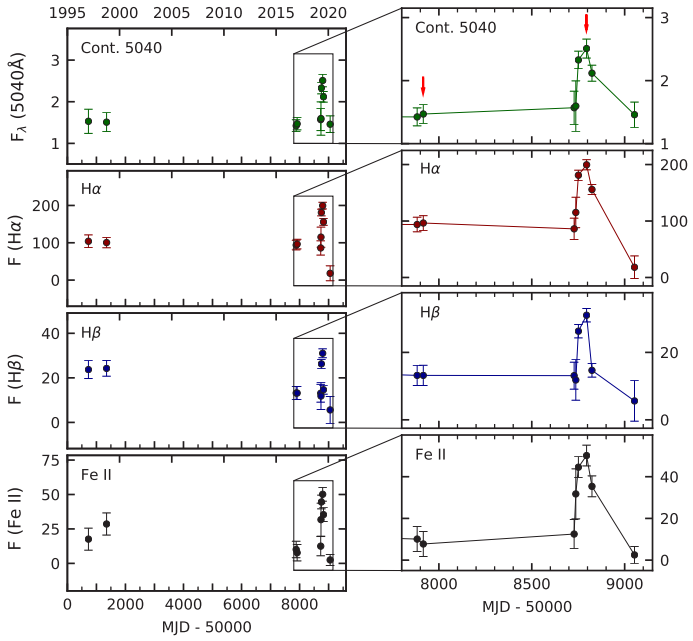
Active galactic nuclei (AGN) exhibit flux variability in all frequencies on time scales of hours to years. Typical *rms* variations are on the order of 10 to 20 per cent, and occasionally changes by a factor up to two are observed in the optical luminosity. In extreme cases, AGNs have shown variability amplitudes of a factor of more than 20 in the X-rays. AGNs that show X-ray flux variations in combination with X-ray spectral variations, that is, when a Compton-thick AGN becomes Compton-thin and vice versa, are called changing-look AGNs. By analogy, optical changing-look AGNs exhibit transitions from type 1 to type 2 and vice versa. In this case, the optical spectral classification can change as a result of a variation in the accretion rate, accretion disc instabilities, or a variation in reddening.

IRAS 23226–3843 has previously been classified as a changing-look candidate based on the comparison of optical spectra taken in the 1990s and optical as well as X-ray data (*Swift*, *XMM-Newton*, and *NuSTAR*) taken after a very strong X-ray decline in 2017. In 2019, Swift observations revealed a strong rebrightening in X-ray and UV fluxes. Wolfram Kollatschny from the University of Göttingen (Germany) and his team aimed to study this outburst in greater detail in the optical. They took optical follow-up observations of IRAS 23226–3843 from 2019 until 2021. The optical spectra — covering the rest-frame wavelength range from 4200 Å to 7100 Å — have been taken with the SALT telescope, as well as with the SAAO 1.9-m telescope.

IRAS 23226–3843 showed a strong optical and X-ray outburst in 2019: The flux of the optical continuum varied by a factor of 1.6 within two months. This corresponds to a factor of three after correction for the host galaxy contribution. The X-ray continuum varied by a factor of five. The Balmer and [Fe II] emission-line intensities showed comparable variability amplitudes during the outburst. The Hα emission-line profile of IRAS 23226–3843 had changed from a blue-peaked profile in the years 1997 and 1999 to a broad double-peaked profile in 2017 and 2019. However, there were no major profile variations during the transient event in 2019, despite the strong intensity variations. The double peaked Balmer lines were extremely broad. In addition, IRAS 23226–3843 exhibits strong [Fe II] blends. This is in contrast to what is expected from Eigenvector 1 studies. One year after the outburst, IRAS 23226–3843 changed its optical spectral type again and became a Seyfert type 2 object in 2020. Throughout all observations, blue outflow components are present in the optical Balmer lines and in the Fe band in the X-rays. Further, a deep broadband *XMM+NuSTAR* spectrum was taken during IRAS 23226–3843's maximum state in 2019. This spectrum is qualitatively very similar to a spectrum taken in 2017, but a factor of 10 higher. The soft X-ray band appears to be featureless. The changing-look character in IRAS 23226–3843 is most probably caused by changes in the accretion rate — based on the short-term variations on timescales of weeks to months.



Line profiles of Hα and Hβ in velocity space after subtraction of the host galaxy spectrum. Absorption components in the blue wing of the Balmer lines (*i.e.*, flux below zero) are shaded in green.



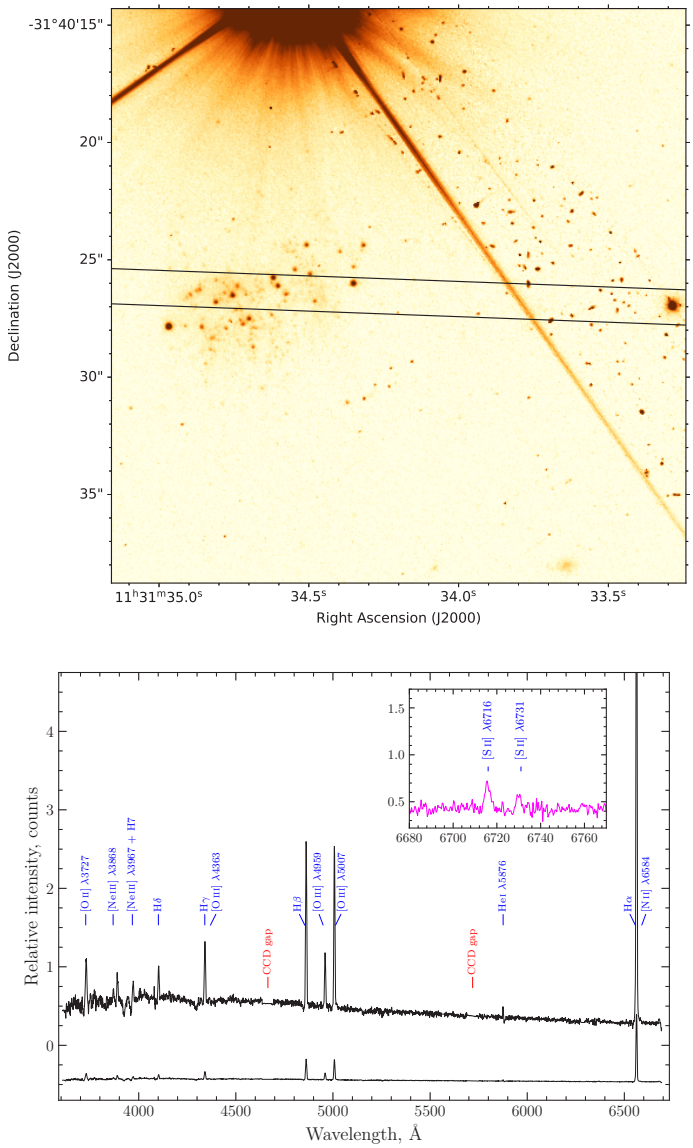
Long-term light curves of the continuum flux density at 5040 Å (in units of 10^{-15} erg s^{-1} cm^{-2} Å^{-1}), as well as of the line fluxes of Hα, Hβ, and [Fe II] (in units 10^{-15} erg s^{-1} cm^{-2}) for the years 1997 until 2020. The right panel shows, in addition to the observations from 2017 and 2020, the variations in 2019 in more detail. The epochs of the deep *XMM-Newton* observations are indicated by a red arrow.

Kollatschny, W., et al. 2023/02, A&A 670, A103: The outburst of the changing-look AGN IRAS 23226-3843 in 2019

Peekaboo:
The extremely metal poor dwarf galaxy HIPASS J1131–31

Igor Karachentsev from the Special Astrophysical Observatory in Russia and his colleagues have discovered a nearby dwarf galaxy with an extremely low heavy element abundance. The gas-rich galaxy HIPASS J1131–31, with a radial velocity of 716 km/s, was detected as an emission source in the neutral hydrogen line in the southern sky survey at the Parkes radio telescope, HIPASS. Karachentsev and his team observed the galaxy with the HST and found it resolved into individual stars. The galaxy is concealed in such close proximity to a bright star that the authors call it 'hidden', aka Peekaboo. The Peekaboo dwarf galaxy is located on the outskirts of a galaxy group at a distance of 6.8 ± 0.7 Mpc. The red giant branch of the system is tenuous compared with the prominence of the features of young populations in the colour–magnitude diagram, inviting speculation that star formation in the galaxy only began in the last few Gigayears.

Spectral observations with SALT reveal HIPASS J1131–31 to be one of the most extremely metal-poor galaxies known, with an oxygen abundance smaller than 2% of the Sun's. The proximity of the discovered galaxy makes it an important target for further study of the cosmic abundance of chemical elements and the nature of young galaxies.



Top: Long-slit position for HIPASS J1131−31. The relatively bright star that is located in the slit was used as the reference star to make sure that a specific part of the galaxy was included. *Bottom*: SALT/RSS optical spectrum with the most prominent lines indicated. The spectrum at the bottom is scaled by 1/8 and shifted to show the relative intensities of the strong lines.

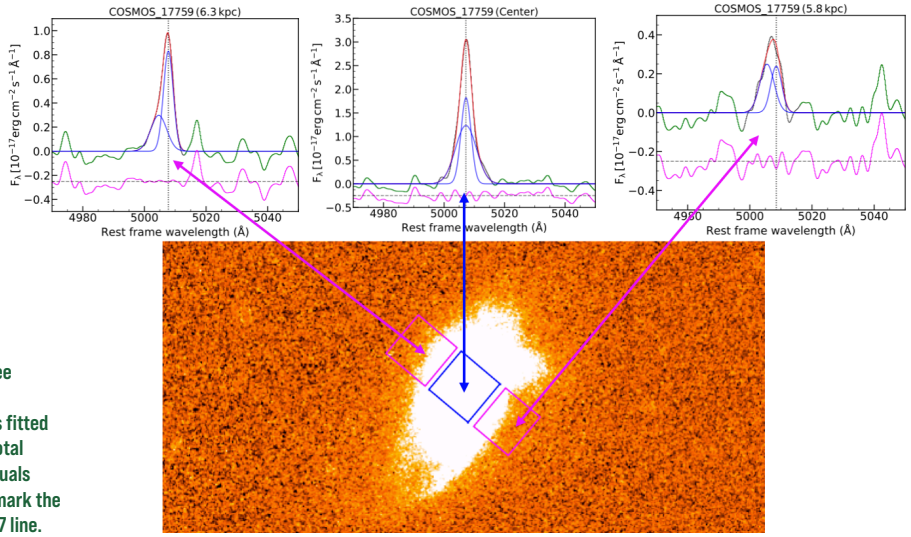
Karachentsev, I. D., et al. 2023/02, MNRAS 518, 5893: Peekaboo: the extremely metal poor dwarf galaxy HIPASS J1131-31

Oxygen profiles of active and non-active green valley galaxies

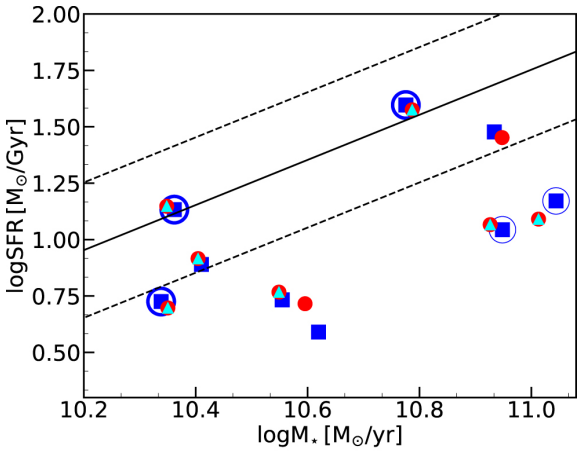
Antoine Mahoro's (UCT/SAAO) PhD studies concentrated on star-forming green valley galaxies with and without active galactic nuclei (AGNs) activity and, in particular, the study of their gas outflow properties. To achieve this, he and his colleagues decided to analyse the spectral properties of far-infrared (FIR) AGNs and non-AGNs in the green valley. They selected the brightest sources that are observable with SALT/RSS from the two samples (eight and six, respectively). To compare the two samples they studied the properties of the [O III] λ5007 emission line, such as the line profile, its symmetry or asymmetry, and they looked for possible signs of outflows.

The spectroscopic analysis showed that AGN profiles are more complex than non-AGN ones, requiring at least two Gaussian components for fitting. They also have higher FWHM velocities than non-AGNs in their core component. In particular, most AGN (5/8) show a blue wing of the line, indicating possible outflows. These wings have a median velocity width of approximately 600 km/s and a velocity offset from the core component in the range of –90 to –350 km/s, in contrast to the non-AGN galaxies, where no blue wings were detected in any of the [O III] λ5007 line profiles.

Using spatial information in the spectra, the authors show that at least three of the five outflow candidate galaxies have centrally driven gas outflows extending across the whole galaxy. The two other cases are ambiguous in that a contribution to a potential outflow signature from rotation (or velocity dispersion) can not be ruled out in the present data. Interestingly, the three unambiguous galaxies are also the galaxies which are located on the main sequence of star formation, raising the possibility that the AGNs in this sample are influencing the star formation of their host galaxies (*e.g.*, through positive feedback). This is in agreement with Mahoro's previous work, where he and his colleagues studied the star formation, morphology, and stellar population properties of a sample of green valley AGN and non-AGN galaxies.



One of the observed galaxies with three different spectra. The plots depict the spectral data (black), the components fitted for emission lines (blue), the overall total best-fitting model (red), and the residuals (magenta). The dashed vertical lines mark the location of the rest-frame [O III] λ5007 line.



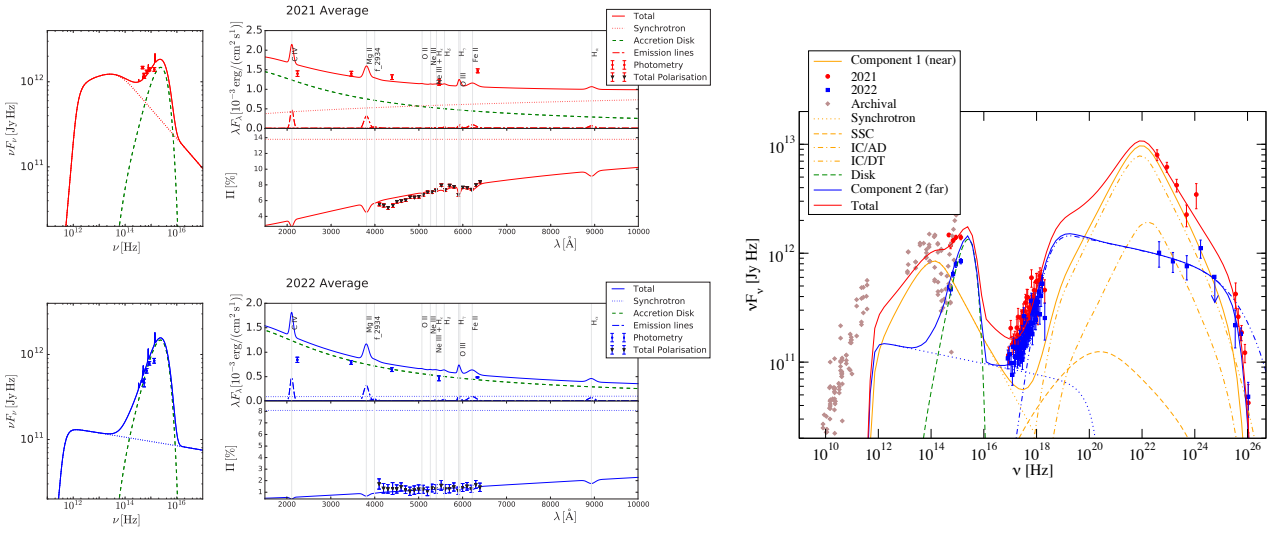
Star formation rate versus stellar mass. Blue squares represent AGNs and red circles are non-AGNs (where cyan triangles indicate those that were observed). Black lines show the main sequence of galaxies with a width of ±0.3 dex. Open blue circles indicate detected blue wings, where the three sources with unambiguous gas flow interpretations are marked with a thick blue circle.

Mahoro, A., et al. 2023/07, ApJ 952, 12: The [O III] Profiles of Far-infrared Active and Inactive Optically Selected Green Valley Galaxies

SALT and H.E.S.S. join forces to understand the strange new state of PKS 1510–089

Blazars are the brightest persistent sources of gamma-rays in the Universe. They possess relativistic jets oriented along our line of sight, which originate from the centre of galaxies where an active nucleus (a supermassive black hole accreting matter onto itself and forming an accretion disc surrounding it) resides. These jets are likely collimated by magnetic fields with helical-like geometries that are difficult to probe as we are viewing them head-on. However, SALT polarisation observations can be used to measure how tangled the magnetic fields are in the emission region in the jet that is responsible for optical-UV radiation. The SEDs and variability of blazars can be described by various theoretical models, ranging from single to multiple emitting regions. In the optical-UV regime, we expect to observe a high degree of synchrotron polarisation from the jet and unpolarised emission from thermal radiation sources, such as the host galaxy or the accretion disc. According to the leptonic model, the X-ray and gamma-ray radiation originate from synchrotron self-Compton and Compton scattering of photons from the broad line region, dusty torus and accretion disc.

A team led by Michael Zacharias (University of Heidelberg, Germany) has regularly monitored the blazar PKS 1510–089 (z = 0.361) simultaneously with H.E.S.S. and SALT in very-high-energy (VHE) gamma-rays and with optical spectropolarimetry, respectively. In July 2021, contemporaneous multi-wavelength observations revealed an abrupt decrease in HE gamma-rays observed with *Fermi*-LAT, optical fluxes (ATOM, *Swift*-UVOT), and SALT optical degree of polarisation, while X-ray (*Swift*-XRT) and VHE H.E.S.S. gamma-ray fluxes remained steady. The team modelled the SEDs and optical polarisation degree using a leptonic blazar emission model, assuming that the accretion disc remained unchanged between 2021 and 2022. An attempt to model both the high state before July 2021 and the low state afterwards with a single-zone model would have required very implausible, extreme parameter changes within about one day. Instead, the source's behaviour is described with two emission regions: In 2021, two emission regions were active: (1) a primary emission region within the extent of the BLR producing synchrotron radiation and high energy gamma-ray radiation, and (2) a secondary emission region further along the jet ($\gtrsim$ 1 pc from the black hole), producing the X-ray and VHE gamma-ray radiation. Radiation from the primary emission region became negligible after 18 July 2021; the 2022 optical-UV fluxes can be explained by the accretion disc and BLR contributions alone. The 2022 degree of polarisation is comparable to the comparison star's and is therefore consistent with interstellar polarisation. The disappearance of the primary region could be explained by rotation of the jet or reduced energy supply into the jet.



Model of the synchrotron SEDs (left most and top part of each of the middle panels) and polarisation degree (lower part of the middle panels) applied to the averaged data of 2021 (red) and 2022 (blue). *Right*: Multi-wavelength SEDs from the primary emission region (orange) and the secondary emission region (blue).

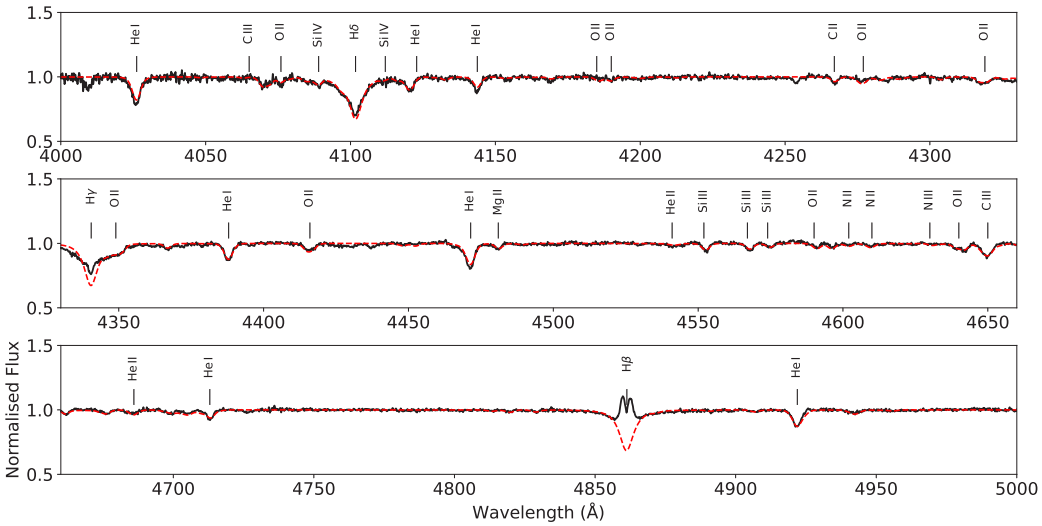
Aharonian, F., et al. 2023/08, ApJL 952, L38: The Vanishing of the Primary Emission Region in PKS 1510-089

SALT spectroscopy of an X-ray binary associated with a supernova remnant

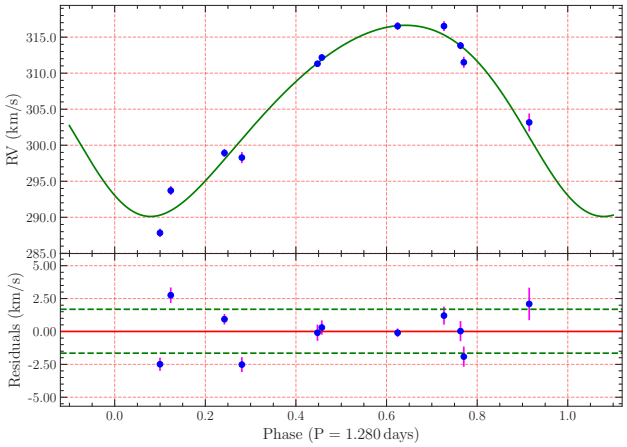
A binary system surviving a supernova (SN) explosion of one of its components could evolve into an X-ray binary in which the compact stellar remnant (a neutron star, NS, or black hole) accretes material from the normal (massive or low-mass) star. The typical time-scale for the formation of X-ray binaries containing NSs (~10^6 – 10^8 yr) is one to three orders of magnitude longer than the time-scale for visibility of SN remnants (SNRs), ~10^5 yr, suggesting that none of such X-ray binaries should be detected within SNRs. However, several NS X-ray binaries were found to be associated with SNRs, challenging the traditional view of the formation time-scales for these objects and requiring explanation.

Spectroscopic observations of mass donor stars in high-mass X-ray binaries (HMXBs), in turn, are necessary to determine whether they are Be or supergiant HMXBs, to measure chemical abundances on their surfaces, and potentially to detect abundance anomalies caused by pollution by SN ejecta. Spectroscopic observations are also needed to determine orbital parameters of HMXBs, such as their orbital periods, eccentricities, mass functions, and so on. The latter parameters can be used to infer SN kick velocities imparted to new-born NSs, to determine orbital parameters of pre-SN binaries and evolution of their post-SN orbits.

Vasilii Gvaramadze (SAI, Moscow) and Alexei Kniazev (SAAO/SALT) with their collaborators report on the results of optical échelle spectroscopy with SALT of the mass donor star BSDL 923 in the NS HMXB XMMU J051342.6–672412 associated with the LMC SNR MCSNR J0513–6724. They found that BSDL 923 is a B0.7 III star with double peaked emission lines originating in a circumbinary disc-like structure. Modelling with the stellar atmosphere code FASTWIND resulted in $T_{\rm eff}$ = 27000 K, log g = 3.22, v sin i ~ 100 km\s, and log (L_* / L⊙) = 5.46 of BSDL 923; it also showed that the surface of this star is polluted with α-elements from the SN ejecta. The authors found also that the NS is orbiting BSDL 923 in an eccentric orbit, with an orbital period of 1.280 d and a semi-major axis of 17 ± 3 R⊙, which is less than or equal to the 25 ± 5 R⊙ radius of BSDL 923. The authors speculate that the NS is embedded in the atmosphere of BSDL 923, either because it was kicked at birth towards this star, or due to inflation of BSDL 923 caused by the energy input from the supernova blast wave. Using SALT/RSS, they searched for possible signs of the SNR shell in the 2D spectrum, but did not find any. This lack of detection is consistent with the young age of this SNR, implying that it is still in the adiabatic phase.



Top:
Normalised and re-binned blue part of the SALT spectrum of BSDL 923 (black line) compared with the best-fitting FASTWIND model (red dashed line). The lines used to determine the stellar parameters are labelled.



Right:
Radial velocity curve of BSDL 923 created on the base of SALT échelle spectra overlayed with a sine fit with a period of 1.280 ± 0.006 d. *Bottom panel*: Residuals of the fit, with an rms of 1.66 km/s.

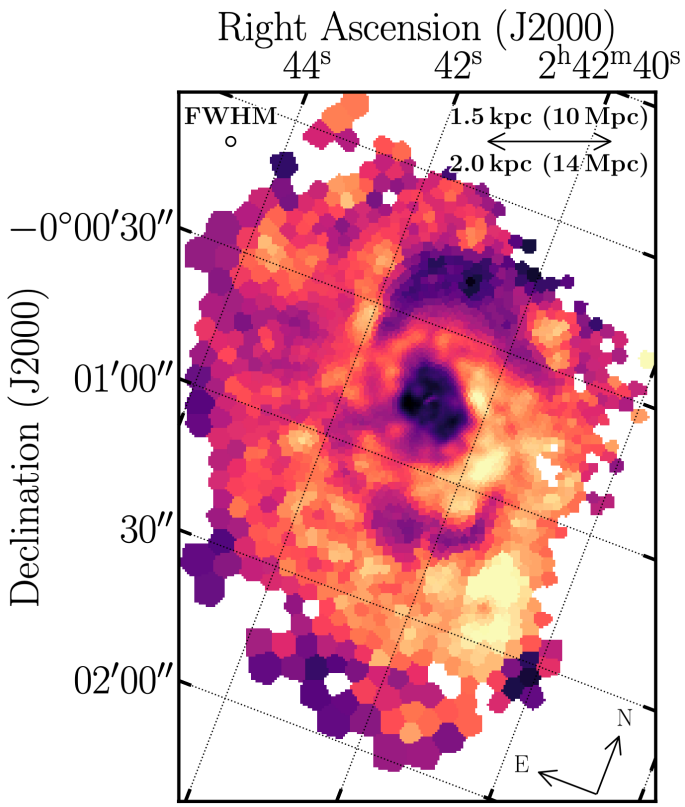
Gvaramadze, V. V., et al. 2023/08, MNRAS 523, 5510: SALT spectroscopy of the HMXB associated with the LMC supernova remnant MCSNR J0513-6724

The kiloparsec-scale influence of the AGN in NGC 1068

Active galactic nucleus (AGN) activity, powered by accretion onto supermassive black holes (SMBHs), is among the most luminous sustained phenomena in our universe. Understanding how AGNs influence their host galaxies across cosmic time is crucial for comprehending the cosmic co-evolution of galaxies and SMBHs. However, discerning the impact of AGNs on galaxy evolution remains a challenge due to the multi-phase, multi-scale, and ephemeral nature of AGN feedback. It is therefore vital to conduct spatially-resolved studies of AGN activity to directly resolve the effects of SMBH accretion on the host galaxy.

Raphael Hviding (Steward Observatory, USA) and his colleagues used SALT Fabry-Pérot (FP) spectroscopy supplemented with RSS long-slit data to observe the nearby obscured AGN NGC 1068. Obscured AGNs are of particular importance as they may represent a distinct phase of galaxy evolution. Despite being the brightest obscured AGN in the sky, it has been difficult to measure the resolved impact of the central engine due to the several-arcminute field of view subtended by the galaxy. FP spectroscopy, critically enabled by SALT, is able to study extended emission regions over nearly a deg^2 field of view.

The FP and long-slit data confirm the existence of kiloparsec-scale ionised features in NGC 1068 that are driven by AGN photoionisation. Critically, they suggest the ionisation features may be understood as a light echo from a burst of enhanced AGN activity ~2000 years ago. These findings provide new evidence and insight into the role of AGNs in the ionisation of the interstellar medium in galaxies. Bursts of AGN activity may therefore have a significant impact on the evolution of galaxies over long timescales.



SALT/FP spectroscopy of NGC 1068 depicting the source of photoionisation across the disc of the galaxy. Darker areas highlight regions where AGN activity drives the ionisation, highlighting two distinct cones on kiloparsec scales from the centre.

Hviding, R. E., et al. 2023/09, AJ 166, 111: The Kiloparsec-scale Influence of the AGN in NGC 1068 with SALT RSS Fabry-Pérot Spectroscopy

SCIENCE HIGHLIGHTS:
Stellar and Galactic astronomy

The SALT survey of chemically-peculiar hot subdwarfs and related stars

Low-mass blue stars that are partially or completely deficient in hydrogen largely represent late stages of stellar evolution. In most cases their histories involve membership of a double star system, either now or in the past. Establishing how such stars were produced requires significant samples, but the stars are rare. Consequently, SALT has been engaged in an intermediate-dispersion survey of all accessible stars classified as helium-rich subdwarfs. The survey includes extreme helium stars, heavy-metal subdwarfs, and various other helium-rich hot subdwarfs. It has discovered many new extreme objects, several of which were reported during 2023 and are described below.

In early studies a very small number of faint blue stars were remarkable in showing weak or absent hydrogen Balmer lines. The identification of extreme helium stars between 1942 and 1980 was followed by the identification of helium-rich hot subdwarfs. From 1990 – 2010, the *GALEX*, Edinburgh-Cape and other surveys identified increasing numbers of 'helium-rich subdwarf B stars' (He-sdB). The spectroscopic definition of the class is no different to that of 'sdOD' in the Palomar-Green survey and also perfectly covers the extreme helium stars. From 1996 onwards, Simon Jeffery and his team at Armagh Observatory, UK, began to ask how stars in all of these groups could have formed, whether the groups were related in any way, and whether they were homogeneous.

Prior to SALT commissioning, attempts to obtain intermediate and high-resolution spectroscopy of many helium-rich subdwarfs had been limited, but the team did learn that a few helium-rich subdwarfs had extraordinary properties. After SALT commissioning, they conceived a survey to classify and analyse 100 helium-rich hot subdwarfs (published in 2021). This included several important discoveries, including potential short- and long-period binaries, so the programme was extended to include radial-velocity and chemical abundance follow-up of key targets, as well as an extension of the intermediate resolution survey.

SALT spectroscopy at intermediate and high resolution is now being combined with parallaxes and proper motions from *Gaia*, photometry from *TESS* and *Kepler*, spectral energy distributions from online databases, and archival spectroscopy. The team's aim is to establish spectral classifications for a sample of 800 programme stars, including fundamental parameters and chemical composition markers wherever possible. Associated projects seek orbital solutions for binaries, pulsation properties for intrinsic variables and measurements of temperature change for rapidly evolving stars.

Classifications for 300 stars

Simon Jeffery reported survey classifications up to May 2022 to the 10th international workshop on hot subdwarfs (2023/01). These are shown in Fig. 1. Helium-rich stars are located at the top of the figure, helium-poor stars at the bottom. The authors identify several key groups, including the early O-type He-sds, the late-O-type and the B-type He-sds. In the middle of the figure are the intermediate helium-rich subdwarfs, with helium classes between 10 and 35. These do not appear to form a homogeneous group, since they include heavy-metal subdwarfs as well as subdwarf / white dwarf binaries like Ton S 415 (see below). As of June 2022, the survey contained 445 reduced RSS blocks, representing observations of 294 unique stars. The report focused on significant results.

For example, following the early SALT discovery of the lead-rich subdwarf EC 22536–5304, the team has identified three additional lead-rich hot subdwarfs including SALT J001235.6–422011, SALT J191223.5–624632, and BPS CS 22956–0094. *TESS* data show that BPS CS 22956–0094 is a short-period binary. All have Drilling spectral types between sdO9.5 and sdB0.5 and helium classes in the range 23 – 27. The authors also identified several new extreme helium stars with $T_{\rm eff}$ and g running all the way from the extreme helium star domain ($\log g < 4$) to the true hot subdwarf domain ($\log g \approx 6$), as well as several extremely hot pre-white dwarf stars (see below).

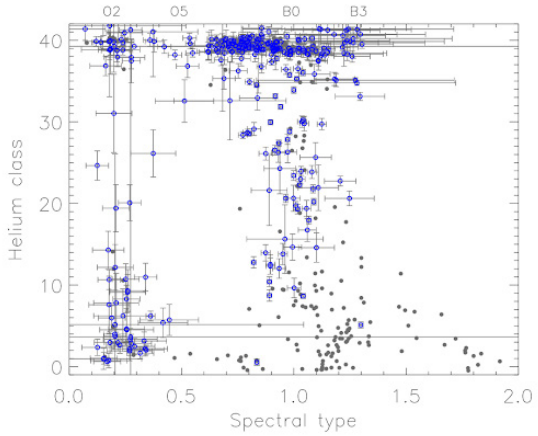


Figure 1 (left): Drilling classifications in terms of spectral type and helium class for stars in the SALT survey of chemically-peculiar hot subdwarfs (blue circles). Classifications from the 2013 Drilling publication are shown as grey dots. Spectral type indices 0.5, 1.0 and 1.5 correspond to types sdO5, sdB0 and sdB5, respectively. Helium classes 0 and 40 correspond to non-detections of helium or hydrogen, respectively, in spectra having resolution R ∼ 2000.

Figure 2 (right): Radial velocity curve, best-fit orbital solution and residuals (*bottom panel*) of Ton S 415, phased to a period of 84.7 min. The radial velocity amplitude is 175.5 ± 1.0 km/s.

Figure 3 (far right): SALT/RSS spectra of hot white dwarfs and pre-white dwarfs. Identifiers are on the left and spectral classes are on the right. Positions of principal lines are indicated at the top. The spectrum of a well-known PG1159 star, the central star of NGC 246, is included for comparison.

Jeffery, C. S., et al. 2023/01, BSRSL 92, 11209: The SALT survey of chemically-peculiar hot subdwarfs

Snowdon, E. J., et al. 2023/01, BSRSL 92, 11278: The close binary fraction of He-rich hot subdwarfs from SALT and TESS

Jeffery, C. S., et al. 2023/02, MNRAS 519, 2321: Hot white dwarfs and pre-white dwarfs discovered with SALT

The close binary fraction of He-rich hot subdwarfs from SALT and *TESS*

At the same workshop, Edward Snowdon presented the examination of *TESS* light curves available for 232 stars in the SALT survey (as of May 2022). Potential binaries were identified and classified according to whether they were due to a reflection-effect (non-eclipsing HW Vir-type systems), or ellipsoidal variables. Of the 24 stars identified to be variable with periods < 2 d, three showed evidence of ellipsoidal deformation, five showed evidence of reflection effects, and none showed eclipses. Follow-up observations to look for radial-velocity variations are being carried out with SALT.

Ton S 415: A close binary containing an intermediate helium subdwarf

One binary first discovered with SALT turns out to be extremely unusual. A publication led by Edward Snowdon (2023/10) describes how this star was first noticed in a merged RSS spectrum; two coadded observations showed remarkable split profiles indicating a radial-velocity separation of 292 km/s. The *TESS* light curve shows an ellipsoidal variation associated with an orbital period of ~85 minutes. The unseen companion is likely to be a white dwarf. Time series spectroscopy was carried out with SALT, using the RSS to obtain between 12 and 24 spectra in five separate blocks of between 15 and 40 minutes. These provided a superb radial-velocity curve (Fig. 2) as well as a high S/N spectrum from which to measure surface properties of the hot subdwarf. Analysis of the ellipsoidal light curve, as well as the radial velocity curve, gives the masses of the subdwarf to be 0.33 ± 0.09 $M_\odot$ and the white dwarf to be 0.47 ± 0.24 $M_\odot$. Ton S 415 turns out to be only the third member of a new class of compact binary containing a low mass hot subdwarf and a more massive white dwarf.

Abundance analysis of a nitrogen-rich extreme-helium hot subdwarf

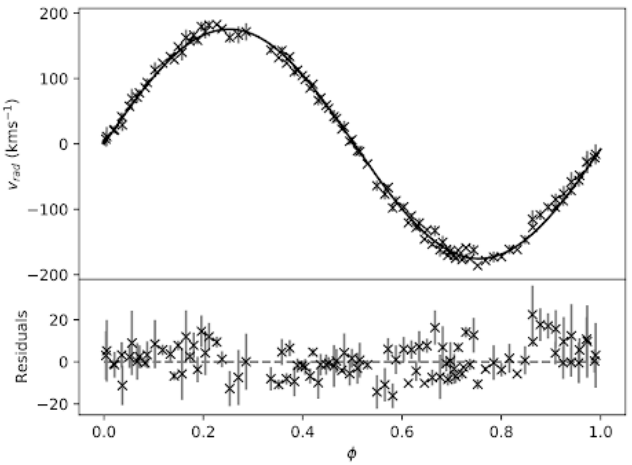
It has been thought for some time that some extreme helium stars, which are the results of double helium white dwarf mergers, will evolve to become extreme helium hot subdwarfs. If so, then the surface chemistries of the two groups should be related. SALT is providing high S/N and high-resolution spectra for sufficiently bright stars to allow testing this hypothesis. In the May publication, Laura Scott and her colleagues examined the HRS spectrum of the extremely helium-rich subdwarf O star EC 20187–4939. It shows a very high surface abundance of nitrogen, about 10 times solar. Neon is enhanced by a factor of about two. The nitrogen abundance is easily explained if the surface material consists almost entirely of CNO-processed helium, whilst the neon could have come from partial processing of the excess nitrogen. Detailed analysis of the surface chemistries of other helium-rich subdwarfs will help to establish connections between stars like EC 20187–4939 and cooler progenitors such as V652 Her and GALEX J1845–4138.

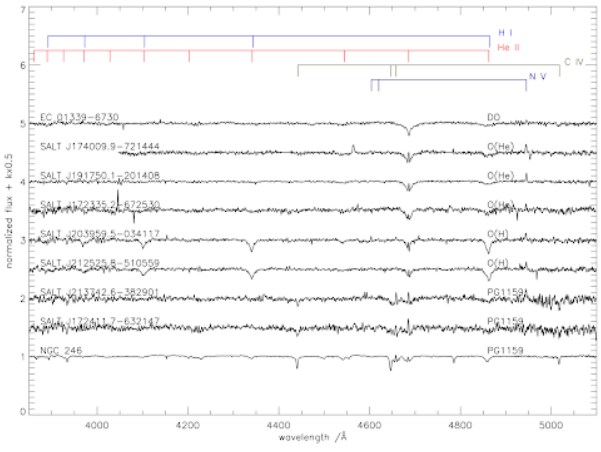
Hot white dwarfs and pre-white dwarfs

The SALT survey sample is inevitably contaminated by stars which have previously been classified as helium-rich subdwarfs but which turn out to be something else, including white dwarfs. Several stars show, for example, weak [He II], [C IV] and/or [N V] emission (Fig. 3). Simon Jeffery and his team (2023/02) analysed eight such objects and found them to include two PG1159 stars, three O(He) stars, two O(H) stars and one DO white dwarf (defined as not exhibiting neutral helium lines). All have surface temperatures in excess of 100 000 K and surface gravities (log g / cm s^{-2}) between 6 and 7 — identifying them as stars which are contracting to become white dwarfs. The two PG1159 stars also turned out to be pulsating, one being potentially the hottest known GW Vir variable. One of the O(H) stars is surrounded by a planetary nebula, whilst the other is the hottest 'naked' O(H) star.

Conclusion

The SALT survey has been productive in identifying significant samples of helium-rich subdwarfs. Several distinct groups are beginning to emerge. Amongst these are many extraordinary individual stars, each of which represents another point in the sparsely represented tracks of evolved stars. SALT's fixed altitude works positively for surveys such as this, with targets distributed widely across the sky. The team's goal to increase the sample to 800 stars is already well within reach.





Scott, L. J. A., et al. 2023/05, MNRAS 521, 3431: Abundance analysis of a nitrogen-rich extreme-helium hot subdwarf from the SALT survey

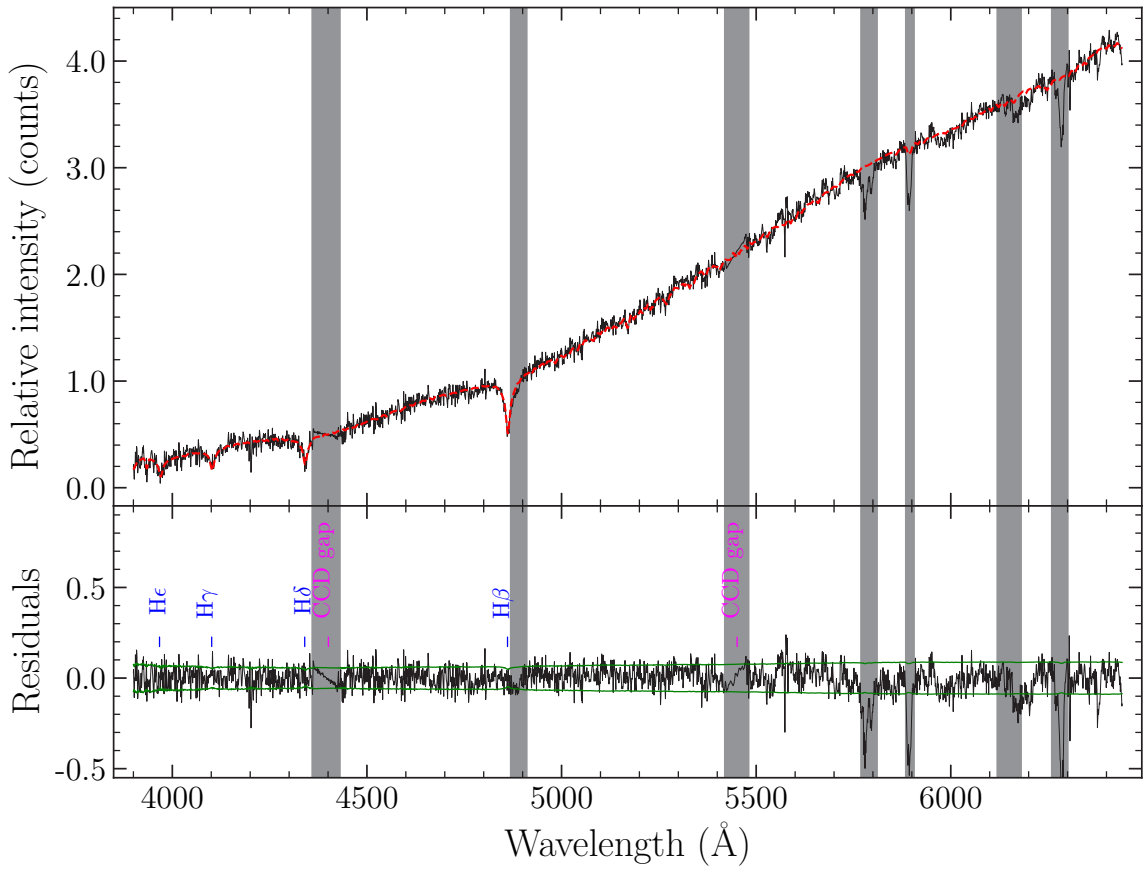
Snowdon, E. J., et al. 2023/10, MNRAS 525, 183: Ton S 415: a close binary containing an intermediate helium subdwarf discovered with SALT and TESS

SALT observes an unusual blue short-period ATLAS variable star

Chris Koen from UWC (South Africa) and his colleagues are working on a long-term project to study ultrashort period main sequence binary stars taken from the ATLAS variable star catalogue. Among others, they selected ATO J280.9765+02.4482 aka ATL 1853+0339 on the basis of its very red colours ($g - i > 2.2$, $r - z > 1.5$) and short period (57 minutes) as a candidate. Photometry at SAAO, however, quickly showed that the variability was due to pulsation, not binarity.

To discover more about the nature of this faint (g = 19.4 mag), unusual object, two successive exposures of 15 minutes each were obtained with SALT/RSS, covering 3400 – 6400 Å. The spectra were co-added and standard reduction techniques applied, including calibration using a spectrophotometric standard. The final, reduced spectrum of ATO J280.9765+02.4482 was analysed with a software developed by SALT Astronomer and co-author Alexei Kniazev to determine parameters of individual components of binary systems such as effective temperature T_{eff}, surface gravity log g, projected rotational velocity v sin i, metallicity [Fe/H], and heliocentric radial velocity V_{hel}, as well as the colour excess $E(B - V)$ of the system.

The model spectrum fitting results are shown in the figure. The best-fitting parameters are T_{eff} = 7300 ± 500 K, log g = 4.2 ± 0.25, [Fe/H] = –0.70 ± 0.15 and A_V = 5.4 mag, *i.e.*, this is a highly obscured low metallicity main sequence A9/F0 star. Given this information, it may be concluded that the star is either a high-amplitude δ Scuti or an SX Phoenicis pulsator. The low metallicity is evidence in favour of the latter; kinematics confirm this. In particular, the SALT-determined radial velocity of 43 km/s could be combined with *Gaia* proper motions to determine a large total velocity of 99 km/s; together with the low metallicity, it may be concluded that ATO J280.9765+02.4482 is a SX Phe star near the thin disc/thick disc boundary. Most SX Phe stars have been found in globular clusters, in the form of blue stragglers, examples in the field being relatively rare.



Results of modelling of the spectrum of ATL 1843+0226. *Upper panel*: Comparison of the observed spectrum (solid black line) with the best-fitting model (red dashed line) obtained with the software. The grey vertical areas show spectral regions excluded from the spectral fit because of their contamination by most prominent diffuse interstellar bands. *Bottom panel*: The difference between the observed and model spectra (black noisy line). The green solid lines indicate 1-sigma errors in the observed spectrum. The positions of identified Balmer lines and CCD gaps are indicated.

Koen, C., et al. 2023/04, AJ 165, 142: Multifilter Time-series Observations of Eleven Blue Short-period ATLAS Variable Stars

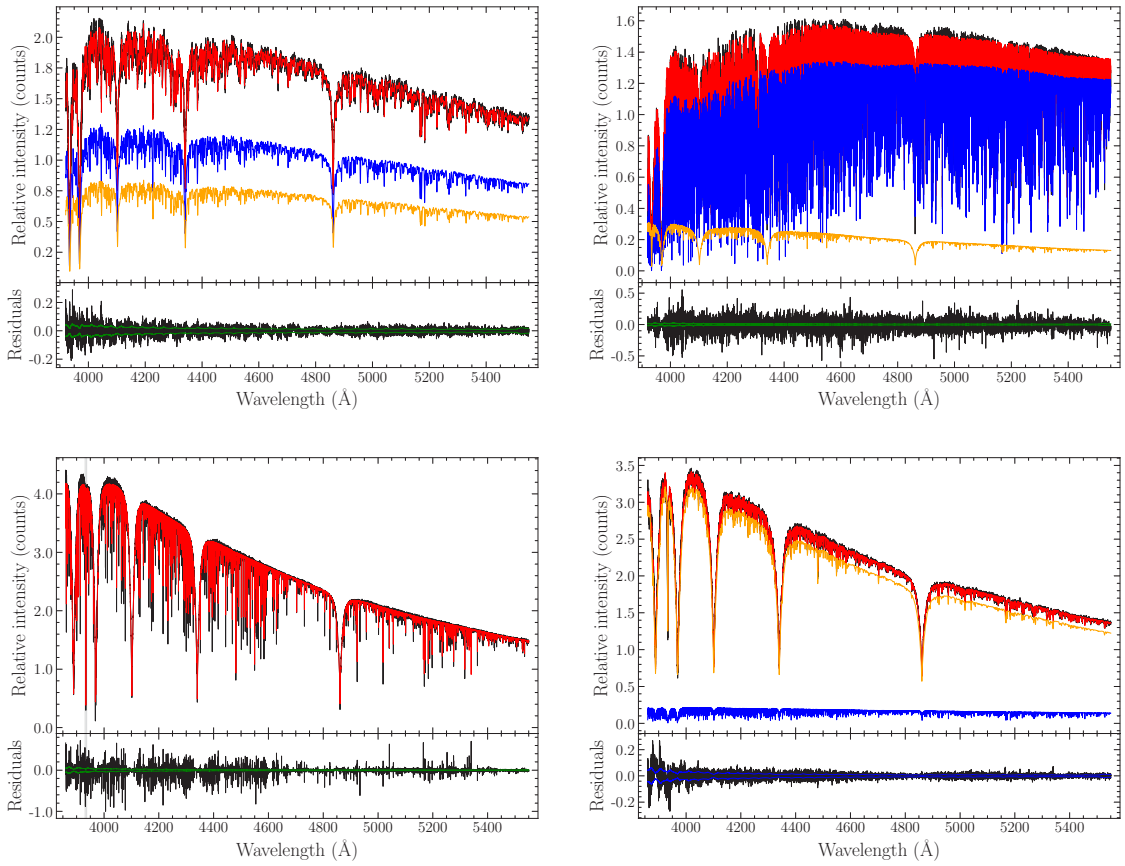
Searching for wide binary stars with non-coeval components

According to current understanding, the formation of binary stars follows one of two scenarios: the fission of rotating clouds of molecular gas during the gravitational collapse and the inelastic collision of stars during the formation of young star clusters. A possible (but obviously rare) phenomenon could be the formation of a binary star by capture, which occurs when two stars pass close to each other. There must necessarily be a scattering medium (*e.g.*, a circumstellar disc or a third star) to which the excess kinetic energy can be transferred.

Obviously, a sufficient (but not necessary) observational condition to demonstrate that a binary system was formed by capture is the difference in age of the components. The age of a star is a rather difficult parameter to define. However, the presence in a wide binary system (where the transfer of matter between the components can be excluded) of a more evolved and yet less massive component is irrefutable evidence for an age difference in the components.

Alexei Kniazev (SAAO/SALT) and Oleg Malkov (INASAN, Moscow) use optical échelle spectroscopy with SALT to study wide binary systems with possible non-coeval components in the Southern sky. For the analysis of the reduced data, the authors relied on the software package `Fitting Binary Stars` (fbs). This software was developed for the analysis of stellar spectra of binary systems and specifically for SALT data.

SALT échelle spectra were compared with two-dimensional spectral classes and component masses estimated from the spectral classification. The situation where the less massive component evolved further from the main sequence (MS) can be considered as a binary system formed by capture. No binary systems with components of different ages were found among the four systems in this study. Taking into account previous studies, the fraction of such binaries (*i.e.*, binaries formed, presumably, by capture) is thus not higher than 0.06 per cent.



The results of the fit of the four systems, HD 20121, HD 26722, HD 114330 and HD 187949. *Top panels*: Results of the fit in the spectral region 3900 – 5550 Å. The observed spectrum is drawn in black. The two components found are shown in blue and orange respectively, with their sum shown in red. *Bottom panels*: Difference between the observed spectrum and its model (black), with errors that were propagated from the HRS data reduction (continuous green line).

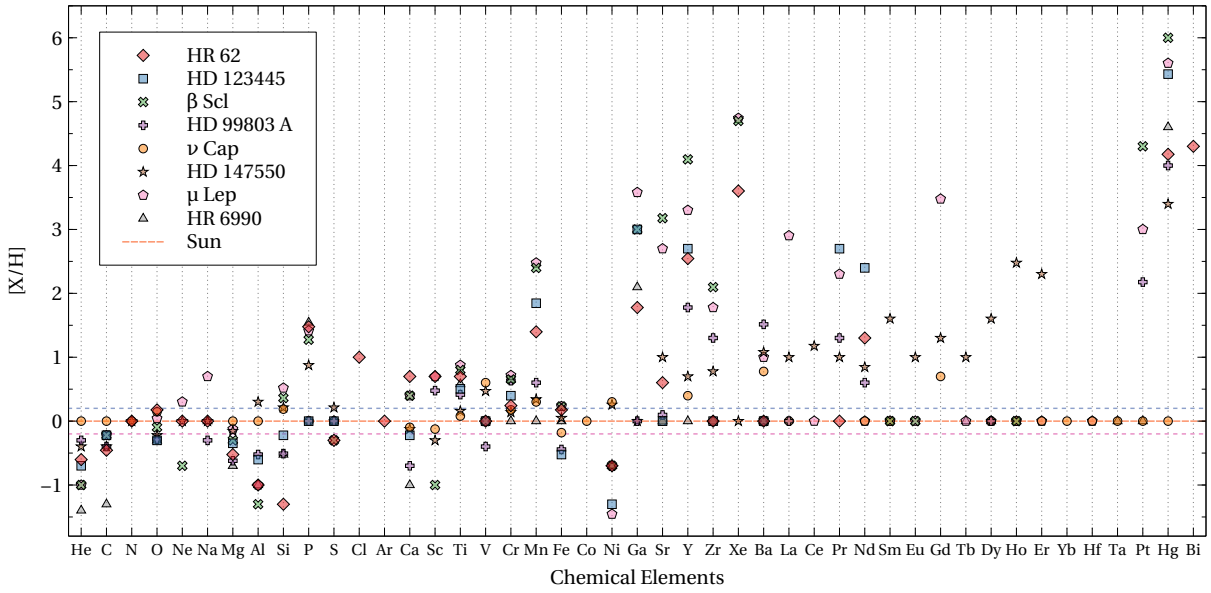
Kniazev, A., et al. 2023/05, RAA 23, 055021: Searching For Wide Binary Stars with Non-coeval Components in the Southern Sky

The surface composition of six newly discovered chemically peculiar stars

Richard Monier from the Observatoire de Meudon (France) and his colleagues have performed a detailed abundance study of six bright, mostly southern, slowly rotating late B stars: HD 1279 (aka HR 62; type B8 III), HD 99803 (B9 V), HD 123445 (B9 V), HD 147550 (B9 V), HD 171961 (aka HR 6990; B8 III) and HD 202671 (B5 II/III), hitherto reported as normal stars. In the spectra of the six stars, the [Hg II] line at 3984 Å line is clearly seen and numerous lines of P, Ti, Mn, Fe, Ga, Sr, Y, and Zr appear to be strong absorbers.

A comparison of newly acquired and archival spectra of these objects with a grid of synthetic spectra for selected unblended lines, reveals large overabundances of P, Ti, Cr, Mn, Sr, Y, Zr, Ba, Pt and Hg and underabundances of He, Mg, Sc and Ni. The effective temperatures, surface gravities, low projected rotational velocities and the peculiar abundance patterns of the six investigated stars show that they are new chemically peculiar stars, mostly new HgMn stars, and are reclassified as such.

The evolutionary status of these stars has been inferred and their ages and masses estimated. The two most massive objects, HD 1279 and HD 202671, might have evolved away from the main-sequence recently, while the other stars are main-sequence objects. HD 99803A is a sharp lined HgMn star with grazing eclipses; from *TESS* and MASCARA photometry the authors determined an orbital period of P_{orb} = 26.12022 ± 0.00004 d.



Comparison of the abundance patterns of the five newly-discovered stars together with that of the superficially normal star ν Cap (HR 7773). Also shown are the two classical HgMn stars μ Lep and β Scl.

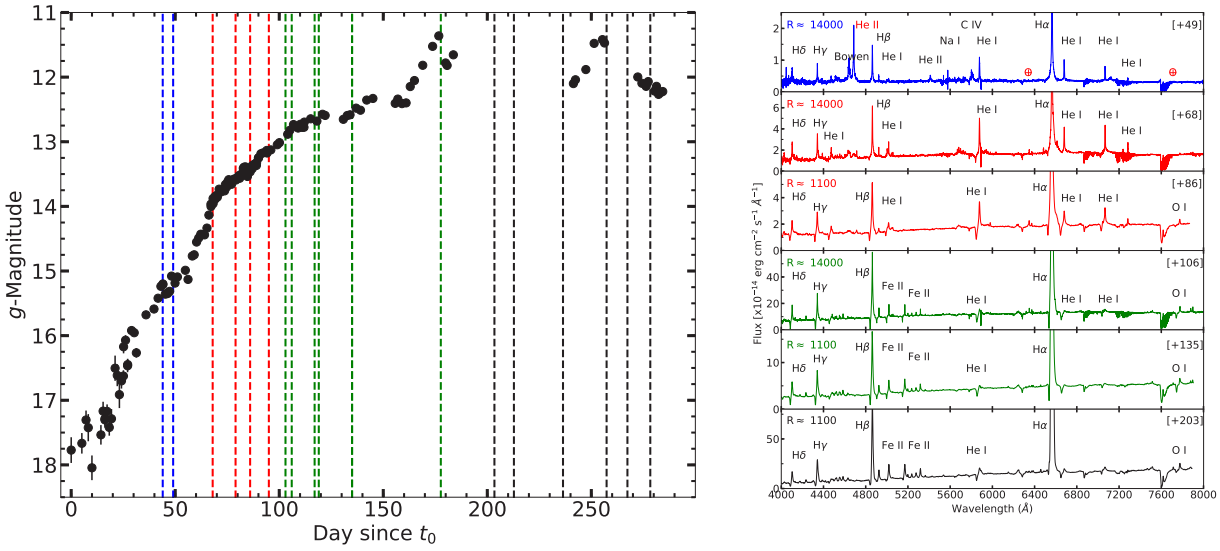
Monier, R., et al. 2023/08, AJ 166, 54: The Surface Composition of Six Newly Discovered Chemically Peculiar Stars. Comparison to the HgMn Stars mu Lep and beta Scl and the Superficially Normal B Star nu Cap

Catching a nova X-ray/UV flash in the visible?

Classical novae are transient thermonuclear eruptions occurring on the surfaces of accreting white dwarf stars in interacting binary systems. The eruption leads to the ejection of most of the accreted envelope and an increase in the visible brightness of the system by 8 – 15 magnitudes. Novae exhibit a diversity of optical light curves with some rising to visible peak in a few hours, before declining rapidly by several magnitudes in a matter of days, while others rise to visible peak over days/weeks and then show a very slow decline over months. Nevertheless, whether slowly or rapidly evolving, all novae are discovered at least 5 – 6 magnitudes brighter than their quiescent magnitudes before further climbing to visible peak.

Gaia22alz was discovered by *Gaia* in February 2022 as a Galactic optical transient at a *G*-band magnitude of around 16.8 mag (1.5 magnitudes above quiescent brightness of 18.3 mag). ASASSN observations of the same field revealed that the transient started brightening slowly from quiescence on 25 January 2022. SALT spectroscopic follow-up obtained on 10 March showed relatively narrow (FWHM ~ 300 km/s) emission lines of Balmer, [He II], [N II], [C IV], and [He I]. This led Elias Aydi from Michigan State University (USA) and his colleagues to conclude that the transient is possibly a dwarf nova outburst, or something more exotic of unknown nature, particularly due to the gradual increase in brightness. A few weeks later, as the transient continued brightening slowly, the spectra showed dramatic changes, with P Cygni profiles of Balmer, [He I], and later [Fe II] developing (with velocities of around 1500 km/s), while the narrow emission lines of high-excitation lines of [He II], [N III], and [C IV] completely disappeared. As the transient rose to a peak brightness of around 11 mag and the spectra developed features characteristic of classical novae, it became clear that Gaia22alz is an unusually slow classical nova, characterised by an unprecedented slow and gradual rise to a visible peak that lasted around 180 days.

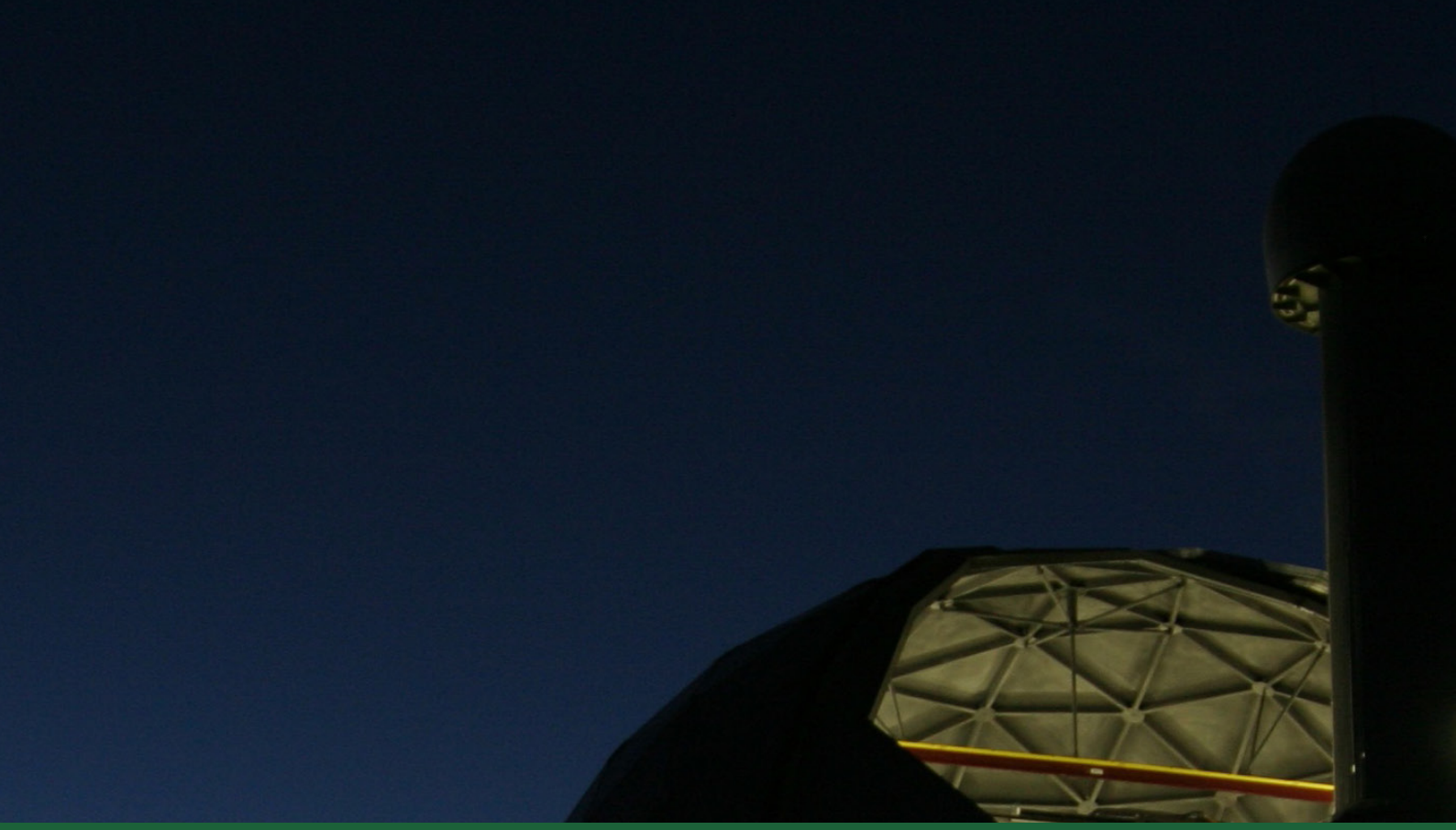
The publication focuses on the spectral development of the nova during this gradual rise to visible peak, particularly during the first 50 days, where the spectral features were inconsistent with that of a classical nova. The presence of high-excitation narrow emission lines of [He II], [N III], and [C IV] during the early days of the eruption, indicating emission from a very hot source, led the authors to conclude that Gaia22alz was first observed during a phase known as the UV/X-ray flash where most the emission from the eruption is emitted in the X-rays and UV, before the accreted envelope of the nova is fully expelled. This phase typically lasts for only a few hours in other novae and is often missed. However, in the case of Gaia22alz this phase seems to have lasted for several weeks, consistent with the gradual rise from quiescence. This gave the team the chance to observe and characterise a phase in a nova eruption that is poorly constrained and understood. In the era of all-sky surveys, one can expect to detect more novae during these early and critical phases of their outbursts, which will allow us to observe and study them with fast response large telescopes like SALT, leading to constraining the physical mechanisms that are in play during these enigmatic eruptions.



Left:
The ASASSN optical *g*-band light curve of nova Gaia22alz during the first 300 d of the eruption. The colour of the dashed lines represent different stages in the spectral evolution, namely the early-rise, mid-rise, late-rise, and post-optical-peak (blue, red, green, and black lines, respectively).

Right:
The spectral evolution of nova Gaia22alz, representing the different spectral stages. Numbers between brackets are days after t0. The resolving power R of each spectrum is added on the left-hand side of each panel.

Aydi, E., et al. 2023/09, MNRAS 524, 1946: Catching a nova X-ray/UV flash in the visible? Early spectroscopy of the very slow Nova Velorum 2022 (Gaia22alz)



SCIENCE HIGHLIGHTS:
Ongoing research

A number of exciting SALT science projects are either close to being published or are longer-term projects that may lead to publications on selected objects of interest, awaiting completion of the final science goals. The following section gives an overview of a small selection of these.

Over the two semesters in 2023 (2022-2 and 2023-1) a total of 107 proposals were accepted by the various TACs (another 16 had been carried over from previous semesters). Nine of these were DDT proposals, receiving a total of 105 kiloseconds of observing time. There were five commissioning proposals, dealing with Polarimetry, RSS throughput and the HRS high stability mode pipeline (174 kiloseconds). Only one Large Science Proposal (LSP) had been submitted in 2023, which is the ongoing transient science programme led by David Buckley. In total, there were 77 normal science proposals (SCI), 25 multi-semester proposals (MLT) and six OPTICON-Radionet proposals (ORP).

While nine DDT proposals were submitted in the semesters 2022-2 and 2023-1, there are five refereed publications in 2023 presenting results from past DDT proposals, three of which can be found in the Science Highlights section (by Koen, Kollatschny and Mahoro). All five are based on DDT observations from 2019 and 2020. According to the statistics, about a quarter of publications presenting DDT data are published within a year of observation (based on 41 publications to date).

Observing the transient Universe

The SALT Large Science Programme (2021-2-LSP-001) on transient follow-up, led by David Buckley (SAAO/UCT/UFS), continues to be very productive, with 14 refereed papers published in 2023, including one each in Nature and Nature Astronomy. Be the end of 2023, another 12 refereed papers were either in press (6) accepted (4) or submitted and have appeared on the arXiv (2). There are also a number of additional follow-up papers which make use of LSP data or expertise within the collaboration.

SALT is ideally suited for most transient follow-up (fast transients, like GRBs, are more challenging). The queue scheduled operation provides the rapid response required (within days, or even minutes) and having the full suite of instruments available at all times allows for the observer to quickly switch between them, depending on the science requirements. Targets for follow-up observations are chosen by (reasonable) request from a programme investigator, or sometimes from external collaborators. Priorities are determined through discussion as well as the nature of the transient. For example, fast transients like GRBs need “P0”, as do time-critical targets. The programme, which began in earnest in 2018, currently involves 68 co-investigators, most from SALT partners, but also some external collaborators. Five SALT partners are involved in the programme: South Africa, Poland, UKSC, IUCAA and UW. The co-investigators include 14 postdocs or early career researchers and 12 postgraduate students.

Observations for the year 2023 comprised a total of 192 successfully completed observations, totalling almost 450 kiloseconds of allocated time. Only 31 observation attempts were aborted or rejected due to unacceptable observing conditions or technical issues. A total of 93 different objects were observed, some more than once, covering the following object classes:

Super soft X-ray sources (SSSs)	—	23.3%	8 objects
Cataclysmic variables (CVs)	—	20.0%	12 objects
Gaia transients	—	13.3%	25 objects
MeerKAT radio sources	—	12.9%	21 objects
High mass X-ray binaries (HMXBs)	—	8.4%	6 objects
Supernovae (SNe)	—	6.4%	5 objects
AGN/nuclear transients	—	6.1%	5 objects
Novae (Ne)	—	4.7%	7 objects
Low mass X-ray binaries (LMXBs)	—	4.2%	2 objects
Miscellaneous eROSITA transients (XRTs)	—	0.7%	2 objects

In 2023, the main focus was on compact white dwarf binaries, comprising SSSs, CVs and novae, with almost 50% of observations. The former sub-class of SSSs follows from transient follow-up of sources mostly discovered by OGLE, with most also occurring in the Magellanic Clouds. Follow-up of CVs was mostly associated with observing magnetic systems, and in particular some discovered in the eROSITA survey, for which there is a very active collaboration with the German institutions involved (MPE and AIP). The *Gaia* transient/variable object class has recently expanded to include a number of DR3 sources tentatively identified as non-accreting black hole binaries from their ellipsoidal light curves in combination with high astrometric scatter. During the year, there has been an increasing number of observations related to sources discovered by the MeerKAT radio array, in particular follow-up of stellar optical counterparts from the SARAO MeerKAT Galactic Plane survey (*e.g.*, transient active chromosphere/corona sources). Follow-up of X-ray binaries did not feature as prominently during 2023 as in previous years, although a new bright outbursting LMXB was observed, with some excellent time-resolved RSS spectra obtained. Also three new discoveries of HMXBs, mostly due to X-ray observations, were observed. Many of these follow-up observations have involved students, both in South Africa and amongst our collaborators.

Major science highlights for 2023 include:

- Discovery of the second example of a white dwarf pulsar aided by time resolved spectroscopy by SALT, observed contemporaneously with MeerKAT observations (published in Nature Astronomy);
- Observations of two new magnetic CVs found through the *Swift* Galactic Plane survey and one from eROSITA;
- Discovery of a magnetar candidate in the LMC;
- Results of a long term spectropolarimetric study of the blazar PKS 1510-089, coordinated with H.E.S.S., featured in a major multiwavelength paper published during the year;
- Discovery of four new Be X-ray binary pulsars in the LMC;
- Identification of a soft and transient ultra-luminous X-ray source with a 6-hour modulation in NGC 300.

Accurate parameters of stars in compact hierarchical triples

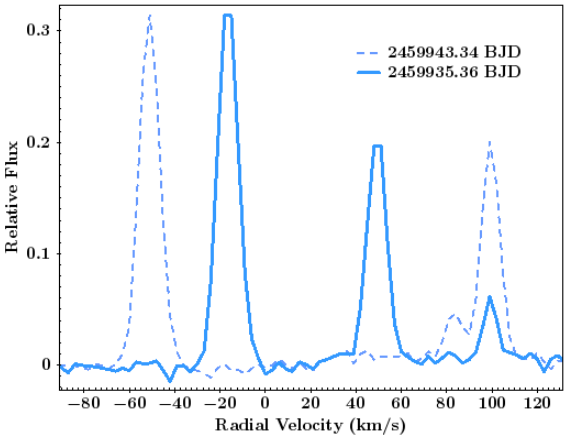
Compact hierarchical triples (CHTs) are systems where a third star moves around an inner binary system with a period less than 1000 days. This causes dynamical changes at shorter time scales and can help to understand the evolutionary changes that can be coupled with the dynamical changes. If the inner binary is an eclipsing binary (EB), it is possible to obtain accurate parameters of all three stars in the system. The recent detection of CHTs using eclipse timing variations of EBs has changed the previously accepted idea that such systems are rare.

A group around Ayush Moharana and Krzysztof Hełminiak at CAMK at Toruń, Poland, has started a long-term programme using SALT/HRS to follow a sample of these systems to obtain time-series spectroscopy of CHTs. This allows the group to obtain radial velocities, which give them precise (< 2% for the inner binary, < 10% for the tertiary) mass estimates. Further, they can disentangle the spectra to get individual spectra to estimate the metallicity and temperature.

The programme has been monitoring some interesting systems like TIC 167692429, an eclipse depth varying (EDV) system, where the inclination of the inner binary changes (Fig. 1). SALT/HRS spectroscopy helps to break degeneracies in constraining its evolutionary phase. The programme also found a new CHT, TIC 387107961, where the tertiary is massive compared to the inner binary stars This system is a possible candidate for mass transfer initiated by the tertiary when it evolves (Fig. 2).

The project has been presented at several meetings and conferences in 2023 by Moharana:

- SALT Science Meeting, Warsaw, Poland
- The Alpha Centauri System: Towards new worlds, Nice, France
- European Astronomical Society Meeting, Kraków, Poland
- Polish Astronomical Society Meeting, Toruń, Poland



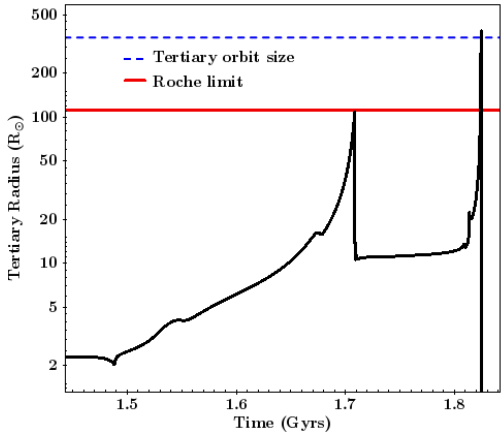
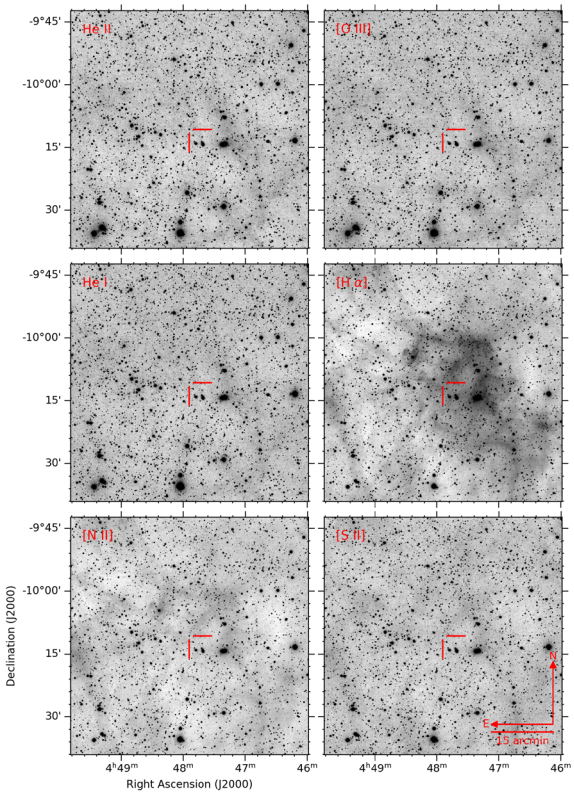


Figure 1:
Broadening functions of the EDV system TIC 167692429 system showing the relative fluxes of primary, secondary and tertiary stars (tallest, second tallest and smallest peak, respectively) in the spectra.

Figure 2:
The evolution of the tertiary radius of TIC 387107961 over time. The tertiary will move to the red-giant phase before the inner binary stars, which increases the possibility of tertiary Roche overflow followed by mass transfer.

A possible nova super-remnant surrounding the putative recurrent nova KT Eridani

Just ten recurrent novae (RNe) — which erupt repeatedly on timescales shorter than one century — are known in our Galaxy. The most extreme RN known (located in the Andromeda galaxy), M31N 2008-12a, undergoes a nova eruption every year, and is surrounded by a vast nova 'super-remnant', 134 pc in extent. Simulations predict that all RNe should be surrounded by similar vast shells, but previous searches have failed to detect them. When KT Eri had recently been suggested to be an RN, Mike Shara from AMNH and his colleagues used the Condor Array Telescope to image its environs through multiple narrowband filters. They found a large (~50 pc diameter), Hα-bright shell centred on KT Eri, exactly as predicted. This strongly supports the claim that KT Eri is the 11th Galactic recurrent nova, and only the second nova known to be surrounded by a super-remnant. SALT spectra of the super-remnant demonstrate that its velocity width is consistent with that of M31N 2008-12a, further supporting the claim of discovery of just the second-known nova super-remnant.



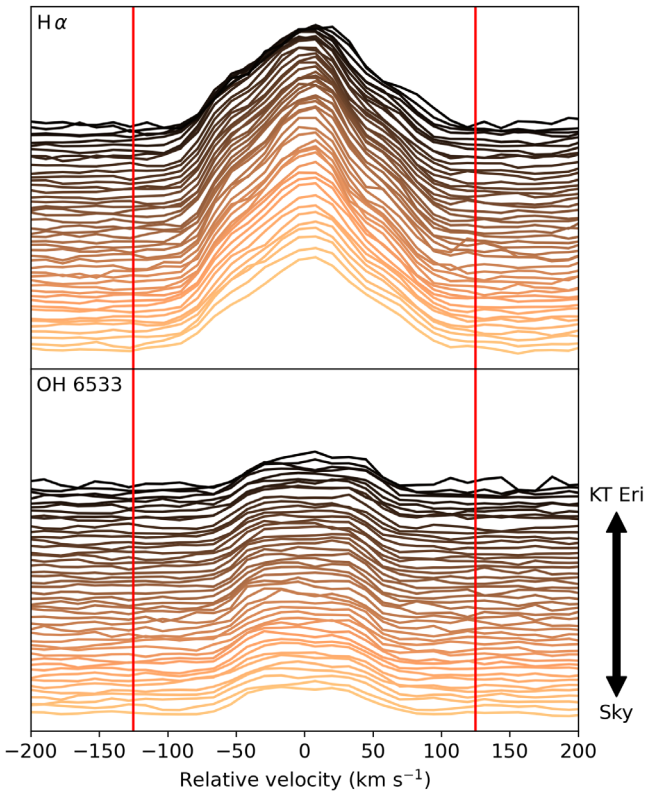


Figure 1:
Various narrow-band images emphasising the Hα-bright shell of the putative recurrent nova KT Eri (marked with red ticks).

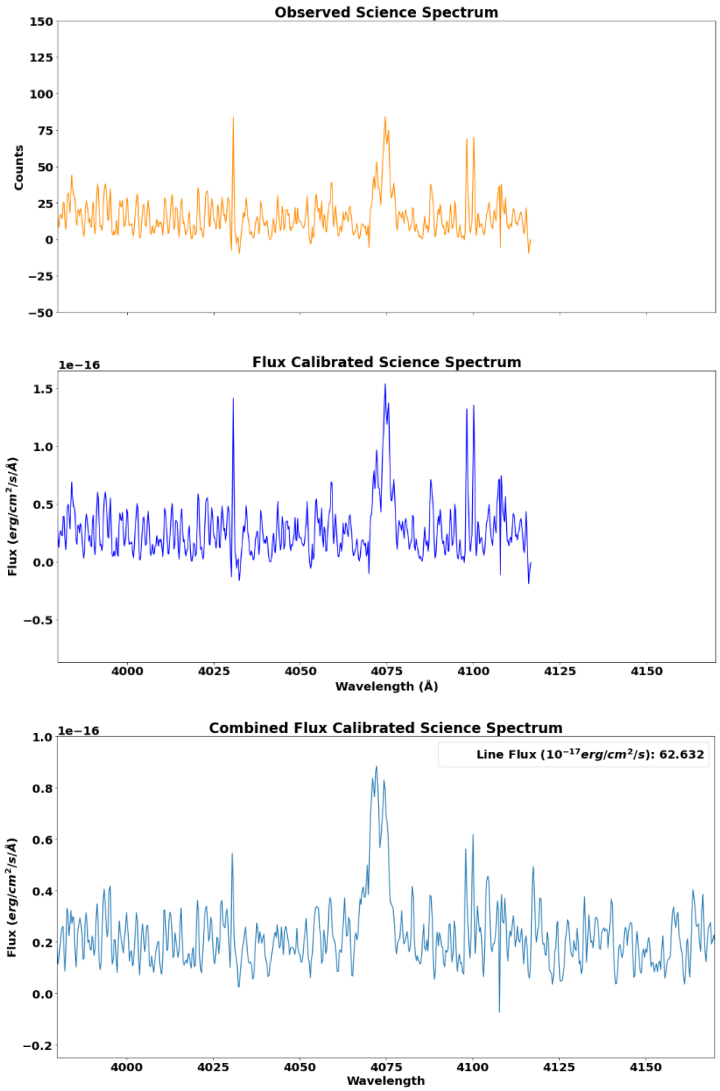
Figure 2:
Hα and neighbouring OH line profiles of the shell of KT Eri from SALT/RSS spectra. The spectra are displayed relative to the lines' respective rest velocities. The binned spectra are coloured and displaced to clarify the evolution of the spectra over the slit, becoming darker and moving upwards in the direction of KT Eri. Vertical red lines correspond to the approximately 0.55 nm full width at zero intensity of the Hα line.

Shara, M. M., et al. 2023/10, arXiv arXiv:2310.17055: Introducing the Condor Array Telescope: IV. A possible nova super-remnant surrounding the putative recurrent nova KT Eridani

Flux calibration for SALT/MOS data

Traditionally, flux calibration on SALT/RSS has been considered a challenging, if not impossible, task due to the variability in primary mirror illumination. This complexity has led to a notable absence of established routines for flux calibration in this context. However, George Kharchilava and Eric Gawiser from Rutgers University (USA) have developed a calibration routine that successfully addresses these challenges. This breakthrough opens new avenues for spectral analysis using the RSS. When picking alignment stars, the programme selects those that also have SDSS spectra taken to use as standards for flux calibration. Most of the authors' MOS masks contain 2 – 3 of these SDSS stars, but the routine can work on any arbitrary number of stars in a given mask. The authors recommend adding plenty of SDSS stars, both on the left and right sides of the mask, to have the complete wavelength coverage. The routine also requires the respective flux calibrated SDSS spectra, which can be obtained from the SDSS public release. The RSS spectra of stars previously observed by SDSS are divided by the corresponding stars' SDSS spectra to produce a sensitivity function. Subsequently, the newly created sensitivity function is subjected to polynomial regression before applying to the science images. This methodology ensures a refined and accurate adaptation of the sensitivity function, ignoring the variance of the data, chip gaps, and any sky line residuals that made it through sky subtraction.

Following flux calibration, another routine then performs a non-linear wavelength reprojection on a combined axis spanning all settings. This is especially important due to varying resolution across gratings. The programme intentionally oversamples data taken with the PG0900 grating in the red for the purpose of having a single spectrum combining all settings without significant loss of resolution in the blue and green settings, aligning with the authors' expectations for the location of the [O II] doublets in their science targets. These routines serve to complement `RSSMOSPipeline`, a pipeline created by Matt Hilton that reduces SALT/RSS MOS data up to wavelength calibration and sky subtraction. Once the data is properly reprojected, it is written as a 2D spectroscopic image in a fits file.



Extracted 1D science spectra of J100048.38+021454.2, an [O II] emitter from HETDEX. *Top and middle*: Spectrum before and after flux calibration in PG3000. *Bottom*: The same target after combining all settings.

Kharchilava, G., et al. 2023/01, AAS 55, 413.03: SALT-RSS Multi-Object Spectroscopy to Reveal Physical Properties of [O II]-Emitting Galaxies at z<0.4 (see also https://aas243-aas.ipostersessions.com/Default.aspx?s=EA-C4-25-C2-9C-76-15-A6-35-01-41-F4-71-0A-69-B3)

SCIENCE HIGHLIGHTS:
Student projects

In compliance with SALT's strategic objective of Human Capital Development, a large number of projects involve students or are initiated by students. Some examples of student projects are presented here. Projects with refereed publications in 2023 can also be found in the research section.

At **Rutgers University** (USA), a number of students work with SALT data under the supervision of Saurabh Jha, *e.g.*, PhD students Conor Larison and Lindsey Kwok, and undergraduate students Michaela Schwab and Colin Macrie.

Undergraduate student **Joleen Barnard** from the University of Free State (South Africa) and under the supervision of Brian Van Soelen, focused on doing spectropolarimetry of a larger sample of blazars for her project. Among others, she analysed the SALT spectropolarimetry of PKS 1510-089 that was used in the H.E.S.S. paper by Aharonian (presented in the science section).

Petro van Rensburg is a 3rd year PhD student at SAAO/UCT (South Africa) under the supervision of Moses Mogotsi, Petri Väisänen and Matthew Bershady, working on the search for traces of outflows and inflows in a sample of nearby starburst galaxies and LIRGs in the SUNBIRD survey. At the 3rd Annual Conference of the African Astronomical Society (AfAS), she presented the analysis of twelve SALT rotation curves. The ionised gas kinematics was traced through the Hα emission line and the neutral gas kinematics through the NaD absorption lines. Petro modelled the gas with multiple components of Gaussian and Gauss-Hermite functions, while the stellar component was modelled with `pPXF`. She then compared the results from the two programmes, best fit models, the gas and stellar kinematics as well as emission line ratios to identify and characterise the gas flows in and around these galaxies.

Near-ultraviolet RSS spectroscopy of primitive asteroids

Sofiia Mykhailova, a 2nd year PhD student under supervision of Tomasz Kwiatkowski (IAO AMU, Poland) decided to determine the physical properties of selected groups of asteroids. The results will be useful for the derivation of models of the creation of the solar system, explanation of the origin of life on Earth, developing strategies of defending the Earth from near-Earth asteroids, as well as preparing for future industrial exploration of these bodies.

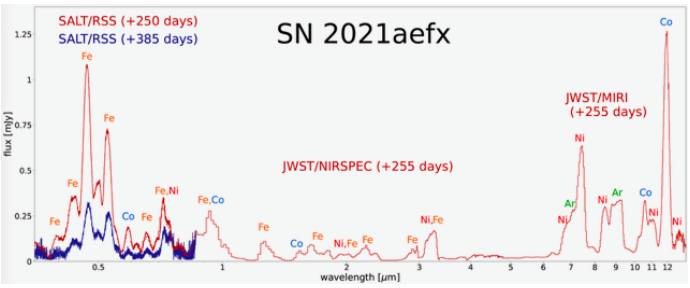
Among many observing techniques used to study asteroid surfaces from the ground, Sofiia will use photometry and spectroscopy. There are many research problems which can be studied that way. Sofiia has selected two of these: the explanation of the unusual behaviour of Barbarian asteroids (using magnitude-phase relations, which can be derived from photometric observations) and the determination of the near-ultraviolet (NUV) absorption of the surfaces of primitive asteroids (using spectra, in which the slope on the continuum in the 0.35 μm – 0.5 μm range can be determined). Additionally, she will use spectroscopy to study the depth of the 0.7 μm absorption band and verify existing solar analogue stars for their applicability in the analysis of NUV asteroid spectra.

SALT will play a major role in the thesis. If all planned observations are performed (some 30+ targets during three years), this will constitute 75% of the observational data for the thesis. It should be mentioned that NUV spectroscopy (320 – 380 nm) with RSS has not been done so far, so this project extends the current capabilities of the RSS. First results obtained with the new PG700 grating show that the method works well.

Sofiia Mykhailova, PhD student, Institute Astronomical Observatory of the Adam Mickiewicz University (Poland)

Supernovae spectroscopy with SALT

Teresa Boland, an undergraduate student at Rutgers University, presented a poster entitled "Supernova Spectroscopy from the Southern African Large Telescope" at the 241st meeting of the American Astronomical Society in Seattle, Washington (USA), in January 2023. Her work featured SALT/RSS optical spectra of the type Ia supernova 2021aefx at late times. As part of her undergraduate honours thesis under Saurabh Jha, Teresa measured the line velocities of various elements and ions in late-time (nebular) spectra. The SALT optical spectra also nicely complemented observations from JWST covering the near-infrared and mid-infrared (published by another one of Jha's students, Lindsay Kwok). SALT allowed the group to get a complete picture of the supernova debris through its late-time spectral evolution.

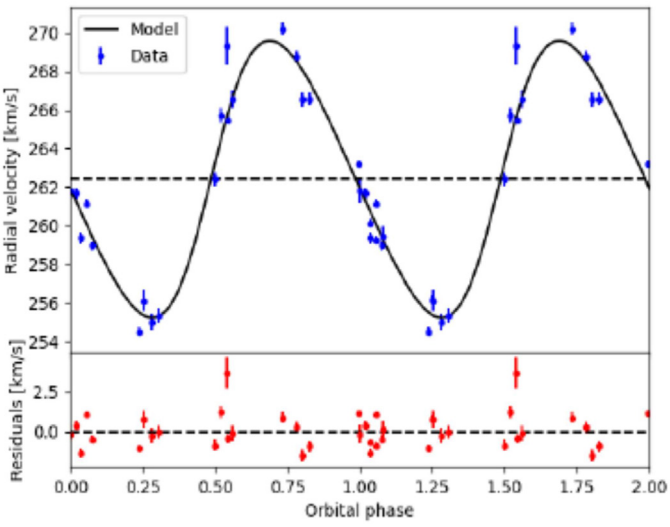


Combined optical+NIR+MIR spectrum of Type Ia SN 2021aefx in the nebular phase. The spectrum has been dereddened and corrected for the host-galaxy redshift. The flux axis uses a nonlinear (arcsinh) scale to better show all the features across a wide range of wavelength and $F\nu$. The optical spectrum from SALT/RSS on 7 August 2022 at a rest-frame phase of +250 days is dominated by forbidden-line emission from iron-group elements.

Boland, T., et al. 2023/01, AAS 55, 107.29: Supernovae Spectroscopy from the Southern African Large Telescope

Kwok, L. A., et al. 2023/02, ApJL 944, L3: A JWST Near- and Mid-infrared Nebular Spectrum of the Type Ia Supernova 2021aefx

The symbiotic star LMC S147: A variability study with SALT



Radial velocity curve of LMC S147, phased with the 1453-day period together with the best elliptical orbit fit (e = 0.15, ω = 270).

Symbiotic stars are long-period interacting binaries, in which a hot white dwarf accretes material from an evolved red giant donor. Due to the multitude of physical processes taking place within these systems, they serve as valuable laboratories for analysing the evolution of binary systems. One such system is the symbiotic star LMC S147, located in the Large Magellanic Cloud. So far, despite over two decades of photometric monitoring, its orbital period remains undetermined.

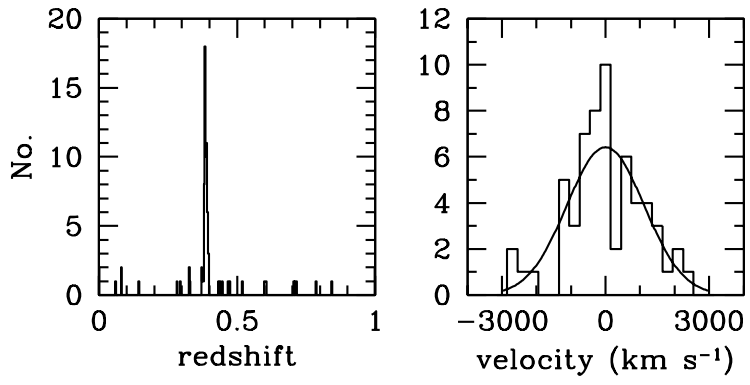
Michał Radziwonowicz, from the Astronomical Observatory of Warsaw University, studied S147's variability for his BSc thesis under the supervision of Krystian Iłkiewicz, using SALT/HRS spectra (PI J. Mikolajewska). The main results of the project were the determination of the orbital period and the spectroscopic orbit based on radial velocities of the cool giant component of LMC S147. He finds that the obtained orbital period of 1453 days falls on the long-period tail of the symbiotic stars' period distribution, which peaks around 600 days.

Michał Radziwonowicz, Astronomical Observatory of Warsaw University (Poland), BSc 2023

A multiwavelength approach to constraining the merger properties of ACT-CLJ0034.4+0225

Peter Doze obtained his PhD at Rutgers University, supervised by Jack Hughes, with a project on using a multiwavelength method to identify and analyse galaxy clusters. The project involved RSS spectroscopy of the galaxy cluster ACT-CL J0034.4+0225, which was suspected to be in a merging state according to X-ray imaging. An ongoing merger should exhibit contrasting galaxy movements, which can be observed using accurate (optical) redshift measurements.

SALT provided 29 unique redshift measurements, which were augmented with measurements from other sources. Cluster membership was determined with the fixed gap method that looked for large velocity differences (> 1000 km/s) from the central body. This method found 60 cluster members between redshifts of 0.37 and 0.40. The redshift and velocity dispersion of the system were determined to be $z = 0.38588 \pm 0.00068$ and σ (1D) = 1119 ± 145 km/s. It was revealed that the two cluster cores, represented by the brightest cluster galaxies, had contrasting velocities, with the eastern and western galaxy moving at +650 ± 140 km/s and –410 ± 150 km/s relative to the cluster redshift, respectively. The SALT redshift information was augmented with radio data, a simulation analysis, and a strong lensing analysis to show that ACT-CL J0034.4+0225 is in fact a previously unrecognised galaxy cluster merger.



Left panel:
Redshift distribution of galaxies in the vicinity of ACT-CL J0034.4+0225, including all available redshifts.

Right panel:
Peculiar velocity distribution of cluster members. This plot filters out all of the galaxies in the left plot with velocity differences greater than 1000 km/s from the central body. The smooth curve is a Gaussian function with the same mean and velocity dispersion as the distribution of cluster members.

Peter Doze, Rutgers University (USA), PhD 2023

Probing the reverse shock in supernova remnants using SALT

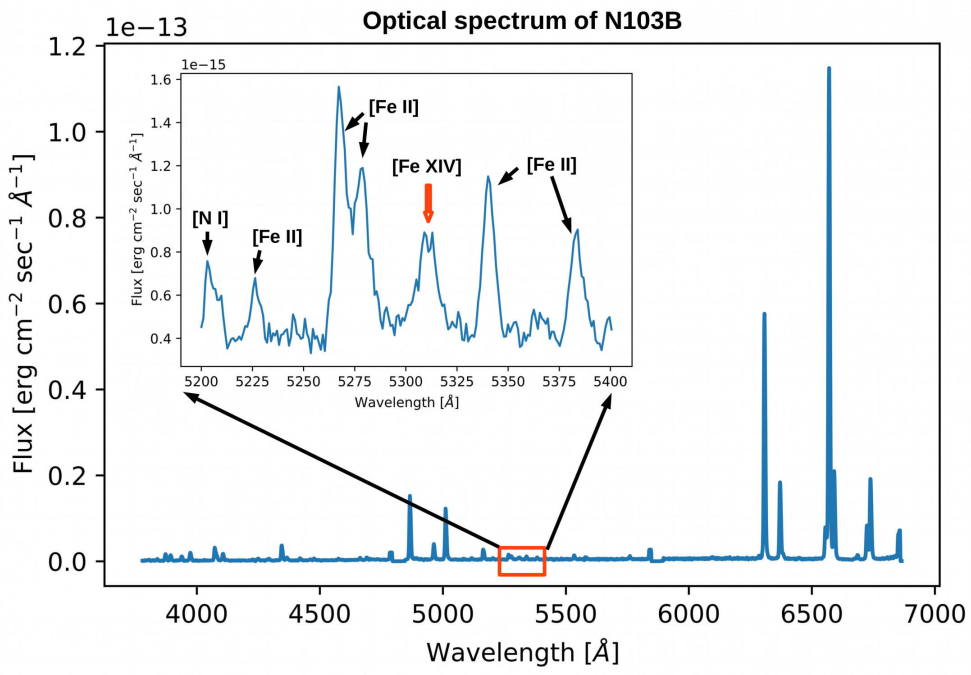
Supernova remnants (SNRs) are an alternate, independent and effective means to study supernovae. While they are a direct probe of astrophysical shocks and chemical enrichment of the surrounding ISM, they also allow strong constraints to be placed on the explosion physics and evolutionary scenarios of the progenitor system, particularly for type Ia explosions. Prasiddha Arunachalam investigated such SNRs in her PhD thesis titled “Shock Kinematics: A promising avenue to understanding Type Ia Supernovae” under the supervision of Jack Hughes at Rutgers University.

One of the chapters deals with coronal emission from SNRs. Of particular importance here is the [Fe XIV] emission line, which traces the hot material trailing the reverse shock (RS) at temperatures ≥ 10^6 K. When modelled for an evolving SNR, the [Fe XIV] emission can be used as an accurate proxy for the RS location. This has important implications towards the properties of the parent explosion. For example, dynamical studies of SNR shocks using the coronal [Fe XIV] emission to inform the RS location have allowed Prasiddha to place constraints on the explosion energy of the progenitor.

The shock-heated material from the RS has been predominantly studied using X-Ray spectroscopy, which suffers from poor CCD-based spectral resolution. The [Fe XIV] line on the other hand, being an optical line at a rest wavelength of 5303 Å, can be well resolved and studied using optical telescopes like SALT.

The aim of Prasiddha’s thesis project was to obtain a first census of the coronal [Fe XIV] line in SNRs. Using SALT/RSS, she conducted long-slit observations of a sample of 14 type Ia SNRs in the LMC at different evolutionary phases: from young ejecta-dominated ones (a few 100 years old) to older SNRs, where the blast wave from the explosion is merging with the ISM (> 20,000 yr). In the entire sample, only one young remnant, SNR N103B, showed conclusive signatures of [Fe XIV] emission along with multiple Fe II emission features.

In 2019, however, a concurrent study was published, revealing at least three type Ia SNRs, including SNRN103B, with coronal emission from the hot RS-heated material, and the scope of the thesis project was adjusted to take this into account. Instead of further analysis and follow up observations with SALT, there was more value in using the new results and combining them with the team’s existing forward shock kinematics. This has allowed Prasiddha to constrain the parent SNs explosion energy of another SNR (SNR 0509–67.5).



Long-slit spectrum of SNR N103B. The coronal line detection is identified by the 5th major peak ~5310 Å in the image.

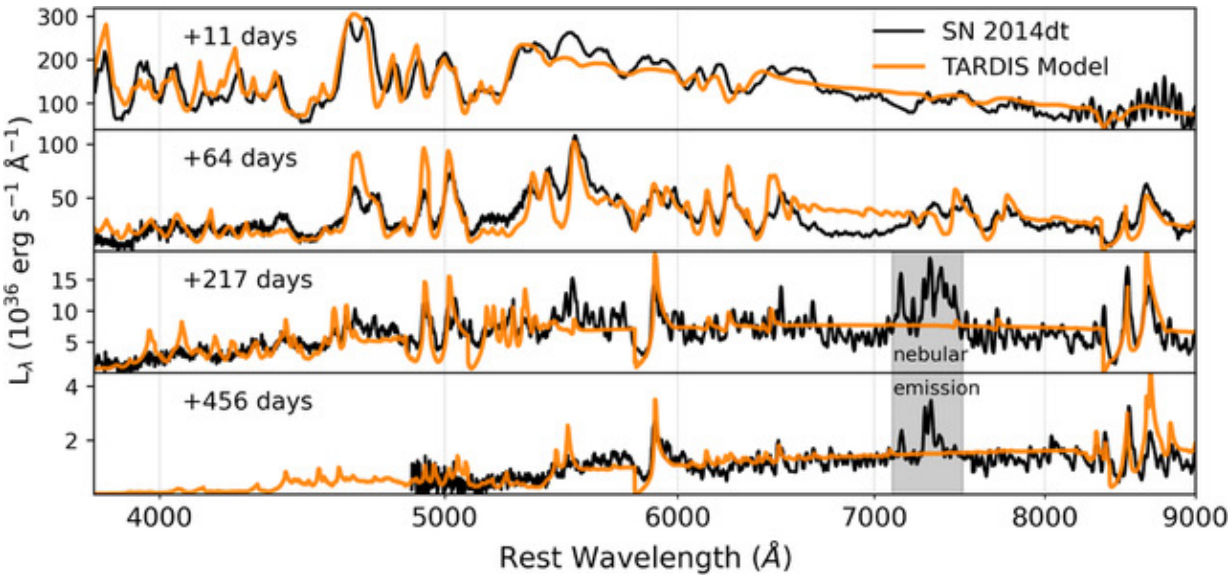
Prasiddha Arunachalam, Rutgers University (USA), PhD 2023

Inside type Iax supernovae: To the photosphere and beyond

Type Iax supernovae (SN Iax) are thermonuclear explosions of white dwarfs. They are 'peculiar' cousins of the normal type Ia supernovae (SN Ia) that have played a starring role in cosmological measurements, based on their use as 'standardisable' candles with a luminosity that can be empirically calibrated based on observed properties. SN Ia were used to discover the accelerating expansion of the Universe, driven by dark energy, a finding that was awarded the Nobel Prize in Physics in 2011. Despite their cosmological importance, we still lack a detailed understanding of the astrophysics of SN Ia explosions. Specifically, we do not know at what mass the white dwarf explodes, with what binary companion star, and how the explosion starts and progresses. One way to gain insight is to study the diversity of white dwarf explosions.

SN Iax are the largest class of peculiar white dwarf supernovae distinct from normal SN Ia. They are typically less luminous than SN Ia, with the explosion debris (ejecta) expanding at somewhat lower velocities than normal SN Ia. All of this points to a less energetic explosion. For her PhD project at Rutgers University, Yssavo Camacho-Neves performed an in-depth study of the spectral evolution of SN 2014dt, a nearby SN Iax. She analysed nearly 70 optical spectroscopic observations of this supernova, including 13 long-slit spectra from SALT/RSS. She used the open-source radiative transfer code TARDIS to model the observed data, finding an excellent match to a known model. This model features a Chandrasekhar mass white dwarf with a weak, pure deflagration (subsonic) explosion. This contrasts from normal SN Ia, which show evidence for detonation (a supersonic explosion burning front). Moreover, the match between the model and the observations continues for over 500 days, an unprecedented time span in white dwarf supernova modelling.

Yssavo also found evidence in the spectroscopic data that the weak explosion did not completely disrupt the white dwarf, perhaps leaving behind a 'bound remnant' that may be driving an optically thick wind. Again this would contrast with normal SN Ia, thought to require the complete disruption of the exploding white dwarf. By differentiating the properties of SN Iax and their progenitors and explosions, and thus showing what normal SN Ia are not, this work is helping to understand what they might be.



Four spectroscopic observations of SN 2014dt are compared to the TARDIS model output from a Chandrasekhar-mass pure deflagration explosion simulation. The excellent match between observations and model extends to hundreds of days.

Camacho-Neves, Y., et al. 2023/07, ApJ 951, 67: Over 500 Days in the Life of the Photosphere of the Type Iax Supernova SN 2014dt

Yssavo Camacho-Neves, Rutgers University (USA), PhD 2023

SCIENCE HIGHLIGHTS:
SALT conference

Science Highlights from SALT

1 – 3 June 2023 in Warsaw, Poland

After several years of only workshops and mini-meetings, the SALT community gathered again for a science conference, this time hosted by the Nicolaus Copernicus Astronomical Center (CAMK) in Warsaw, Poland, in June. The conference followed directly after the 53rd SALT Board meeting, and included approximately 60 participants representing all the SALT partners, with Poland and South Africa having the most participants, and others coming from the USA, UK, India, Germany, Thailand, and Italy.

A very wide array of topics was covered in 38 excellent talks and six posters, highlighting some of the fascinating questions that have been explored using SALT over the past few years. Interesting results and ongoing projects on all sorts of stars and transient phenomena, characterising exoplanet hosts, multiple stellar systems, AGN and galaxies in clusters were presented.

At the start of the conference, Marek Sarna was awarded the CAMK PAN medal in recognition of his leading role in realising Polish participation in the SALT project. He also was the main initiator and co-founder of the Polish SALT Foundation. The unprecedented achievement of starting the first big project that granted Polish astronomers access to a world-class observatory led to joining other large projects, like CTA, LIGO-VIRGO and many others. Realising the importance of competitive observational data, Sarna, as the director of CAMK, urged his colleagues to also gain engineering expertise and managed to secure extra resources for the Center. As a consequence, over four hundred refereed papers ultimately based on SALT data have been published with participation of Polish astronomers. SALT thanks him for his commitment and many valuable contributions as a SALT Board member over the years.

Joanna Mikołajewska and the local and scientific organising committees put together an inspiring and enjoyable conference. As Lisa Crause reflected, “There was a real sense of how much SALT has matured over the six years since the previous conference in Poland, which is most heartening to see.” We look forward to seeing what the next few years hold for SALT!

Photos *(top to bottom)*
Marek Sarna receiving his award.
Jack Hughes (Rutgers University) and Brian Chaboyer (Dartmouth College) at dinner.
Garden of the Italian restaurant where the conference dinner was held.

OPERATIONS

OPERATIONS:
Astronomy operations

The highlight of the year has been the continuing efforts to complete the commissioning of our IFU-fed NIR spectrograph, NIRWALS, and the start of guaranteed science observations for the instrument team towards the end of the year. We have also been working on characterising the high-stability mode of HRS (HRS-HS) in preparation for the commissioning of the laser frequency comb (LFC), which will enable us to expand SALT's research into exoplanets. The construction of the LFC began in August and is expected to be completed in the first half of 2024. Early in the year, RSS underwent a service that included installing new collimator optics which have essentially eliminated all internal scattered light within the instrument.

There have been some challenges this year too, the main problem being the very high losses due to weather, resulting in much less science time and hence lower programme completion rates than anticipated. The combination of the poor weather and unexpected technical issues with SALTICAM and RSS in the second half of the year also had a significant impact on our higher priority completion levels, which are generally the more challenging observations. We also had multiple issues with the DIMM, the telescope that measures seeing on the plateau. The DIMM went offline for much needed repairs and upgrades in June and, due to multiple delays, it is only expected to be back online in early 2024.

In terms of engagements with the community, the highlight of the year was the fantastic conference "Science Highlights from SALT" held in Warsaw, Poland, in June, organised by our Polish partners, led by Joanna Mikolajevska. It was wonderful to see the quality of the research being carried out by the community and also meeting in person some of those familiar PI names in our observing queue.

Another major milestone for the team this year has been the release of the new SALT Web Manager at the beginning of 2023. The new WM is much faster than the old one, large proposals are much easier to navigate, and, most importantly, NIRWALS proposals are also supported. A new PIPT has also been released to the instrument team to enable the submission of NIRWALS proposals. It will be released to the community in time for the shared-risk observations planned to begin in May 2024.

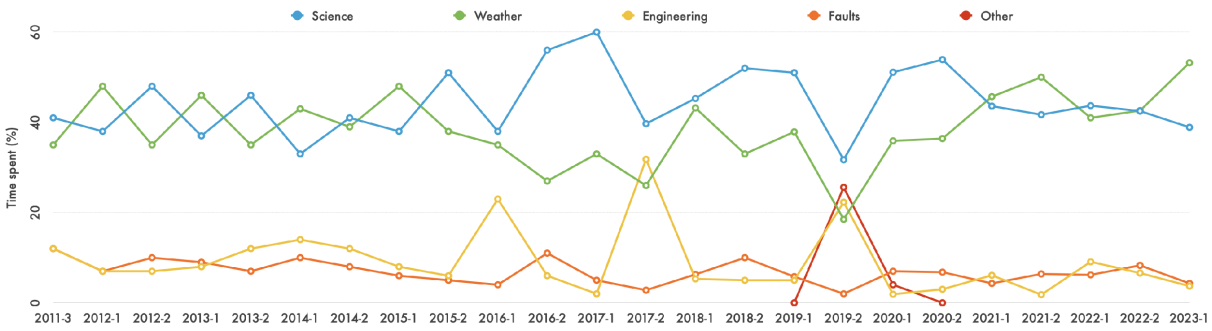
Scientific data reduction pipelines for NIRWALS, HRS-HS and for RSS have been making huge progress this year and all are expected to be ready for the community in the first half of 2024.

Semester statistics

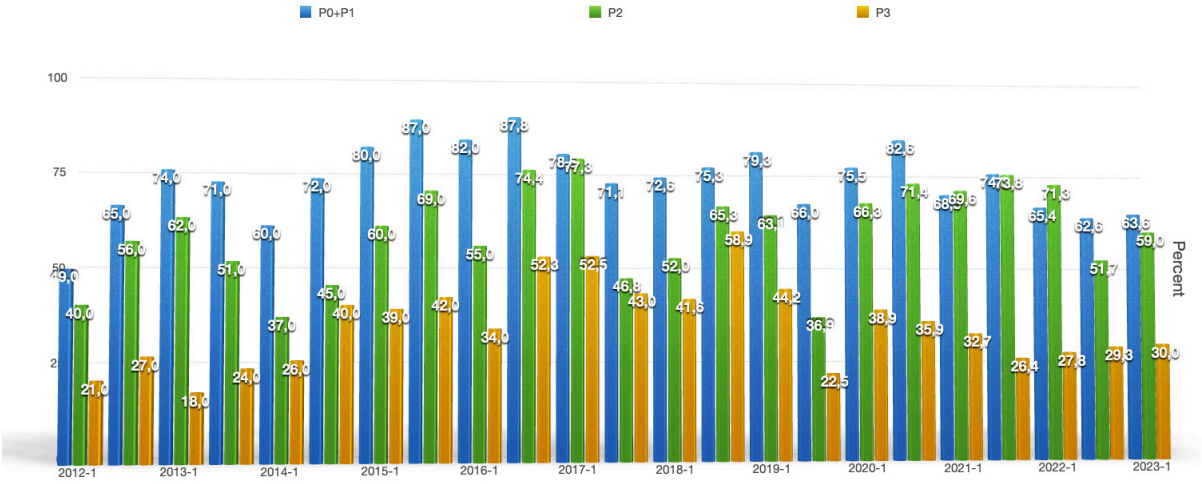
As can be seen from the observing statistics plot below, the record-breaking 50% weather loss we suffered in semester 2021-2 was left in the dust during 2023-1, with a staggering 53.2% weather downtime (to note, we had planned for our usual winter weather loss of 40%). Technical downtime (faults that take the telescope offline) was relatively low at 4.3%. Engineering observations were at 3.7%, mainly spent on HRS-HS observations to characterise the stability of the instrument and NIRWALS commissioning observations. This left us with just under 39% of the time for science observations — the lowest we have had for many years.

Our priority completion levels this year are similar to the last couple of years and lower than expected, again mainly due to the record-breaking weather loss. In addition, significant instrument and/or mode unavailability due to technical faults, which may not reflect in terms of overall technical downtime because we can continue to operate with other instruments, also had an impact on our ability to complete high priority observations in the queue. For example, SALTICAM, which is our main acquisition camera, experienced technical problems with cooling and was offline from 21 September until 28 November. Our backup camera (BCAM) is much noisier and has a much smaller field of view, which made some acquisitions very difficult and, in some cases, rendered some observations impossible.

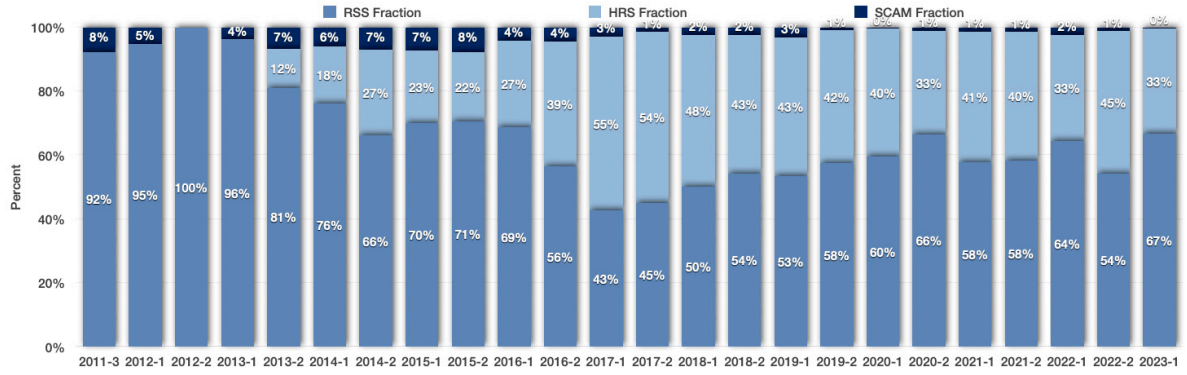
In terms of instrument usage, RSS continues to be our main workhorse instrument, dominating our very best conditions (dark, clear, good seeing nights). HRS, on the other hand, remains our main instrument for bright nights and worse seeing conditions. SALTICAM, due to its lack of guidance and focus control, remains mainly an acquisition instrument.



SALT time usage per semester.



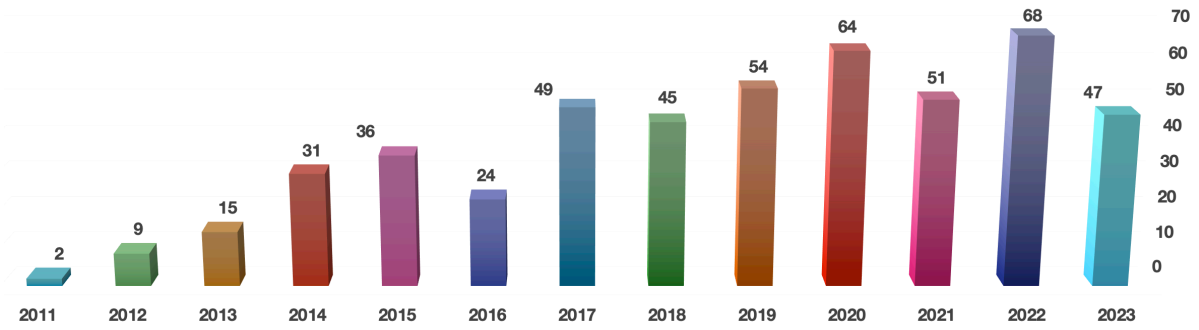
Completeness per priority in percent.



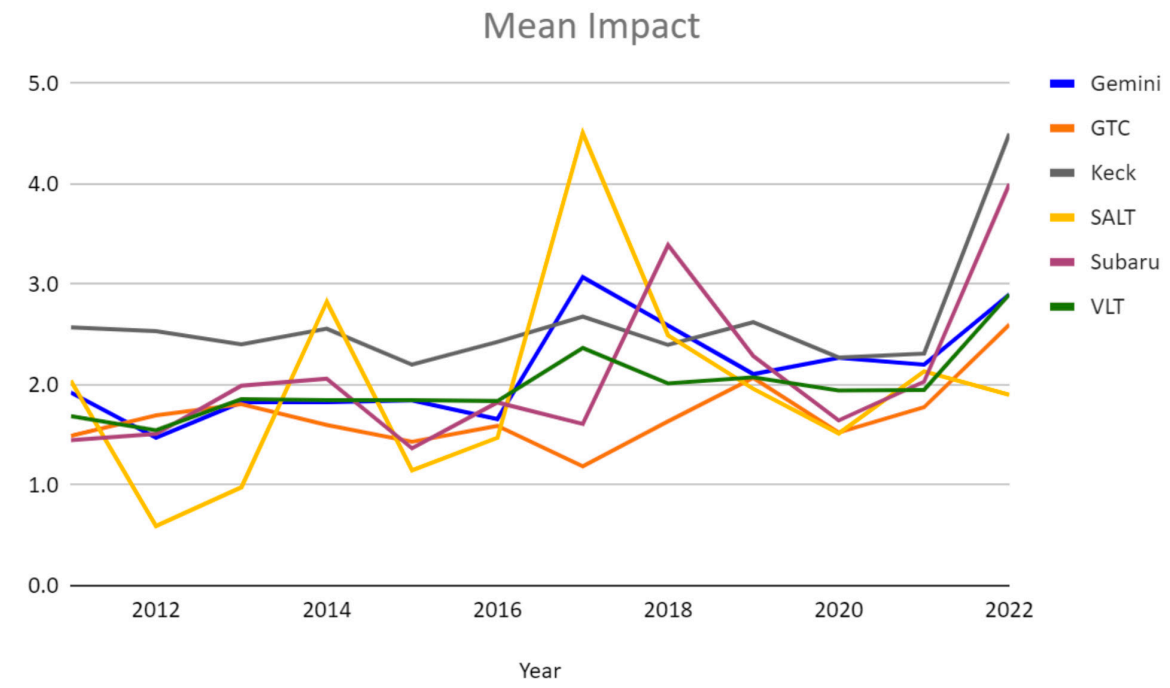
SALT instrument usage per semester.

Publication statistics

This year we saw a disappointing total of 47 refereed SALT publications. However, variations in our publication rate are to be expected year-to-year as we slowly reach steady-state. Overall, SALT continues to follow similar publication growth to other similarly-sized telescopes from around the world.



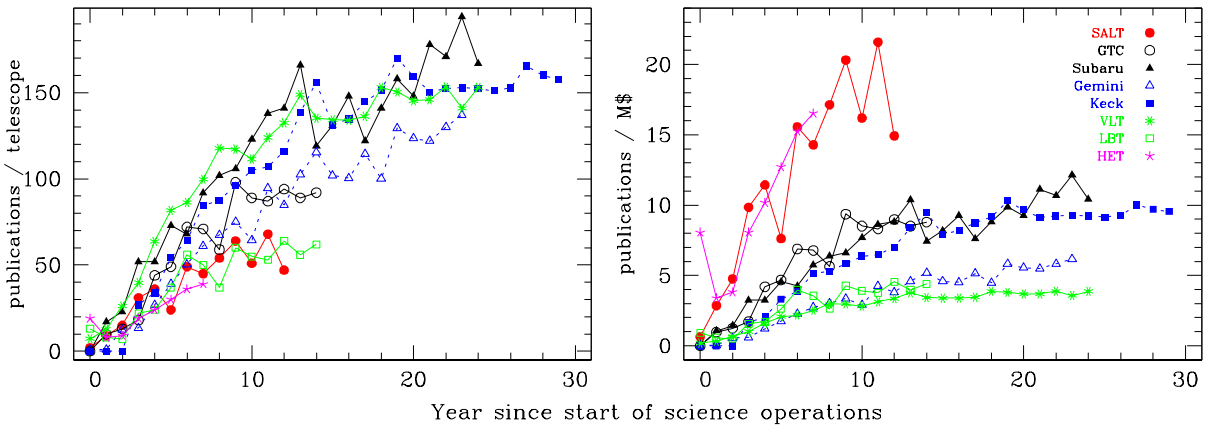
Refereed publications based on SALT science data and including instrument-related publications, from the start of science operations in 2011.



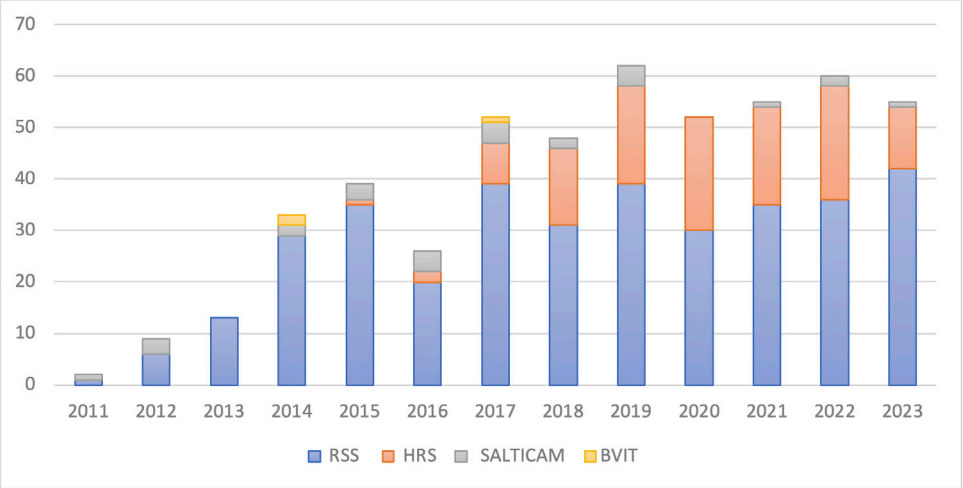
'Mean impact' of large optical observatories, based on citation counts of papers based on the respective facility. SALT is following the broad trend. The peak in 2017 is due to a single, extremely highly cited paper on the electromagnetic follow-up of the gravitational wave event that year. — Credit: Xiaoyu Zhang

Perhaps more important is the 'mean impact' of SALT publications. The figure above is based on the results of the analysis carried out by the Gemini librarian Xiaoyu Zhang. 'Mean impact' in this case means the average citation count in a given year, normalised by the citation impact value of the journal ApJ in that year. The analysis finds that large telescope data papers are on average 2 – 3 times more cited than overall ApJ papers; there may also be smaller implicit effects shaping the curves, depending on which journal, with varied citation impacts, the bulk of given facilities data is published in. SALT is shown to follow similar trends to major observatories around the world, emphasising that SALT is producing good quality and scientifically relevant papers.

In terms of cost per paper, SALT continues to deliver excellent value, with much lower costs than similarly-sized single telescopes around the world.



Refereed publications since science operation started for major telescopes. *Left*: publications per year and per telescope; *right*: publications per year and per operation cost in million US Dollars.



Instrument usage in SALT publications.

RSS continues to be our main source of publications, though HRS contributions have been steadily increasing over the last few years. As mentioned above, SALTICAM's lack of guidance and difficulty with maintaining focus has made it less attractive to our users. BVIT is no longer available.

User support

To improve our efficiency at the telescope, we continue to investigate the observing queue using our semester simulator. To date, we have confirmed that the main limitations for improving the completion level for our higher priority classes is competition for the best weather conditions, as well as popular areas of the sky.

The NIRWALS pipeline development has continued and it is maturing. The expectation is that users will be able to use this pipeline in the upcoming 'shared risk' observations, beginning in May 2024. The description of the pipeline has been accepted as a poster at the SPIE conference in Yokohama, Japan, in 2024.

Enrico Kotze has also been working on an RSS data reduction pipeline, which is expected to be ready for the user community by the end of March 2024. This project, too, has been accepted for publication at the same SPIE conference.

SALT Astronomer Danièl Groenewald has been working on linear spectropolarimetry user support and calibrations, together with the original RSS PI, Ken Nordsieck (UW). Their publication has been accepted as a poster at the SPIE conference.

A new SALT Web Manager (WM), a browser-based application for our users, was successfully launched in 2023. It is much faster than the old WM and also incorporates NIRWALS blocks.

Personnel

SALT Astronomer Rosalind Skelton took on the role of Head of Research at the SAAO in July 2023. Her tasks within the Astro Ops team were consequently adjusted to allow her enough time for her new role.

SALT Astronomer Enrico Kotze announced his intention to not renew his contract (with a focus on pipeline development) after its expiry at the end of March 2024. The position will be advertised at the beginning of 2024.

SAAO Director Petri Väisänen announced his resignation from his position in August 2023, with a planned departure date of March 2024.

OPERATIONS:
Technical operations

The Tech Ops team had a busy year to maintain operations and complete projects while facing resource constraints due to key staff resignations. A resource requirements plan, which includes a project and operations priorities overview, was sent to the SALT Board for discussion and final decision. This is key to ensuring we can alleviate some of the resource constraints for the short term. The biggest constraints are on our software and electronics team, and the SALT Board is fully supportive in providing the financial support where possible. SALT has also hired two short-term contractors to assist with the many outstanding software enhancement tasks that were identified, grouped together, and labelled the SALT Efficiency project. The improvements made to date are already having a positive impact on daytime and nighttime operations.

For the semesters 2022-2 and 2023-1, the telescope's average technical downtime decreased slightly to 6.0%. A large portion of the downtime was attributed to a Tracker Hexapod failure, a SALTICAM cryocooler pipe leak, intermittent RSS controller failures, and a corroded RSS detector cryostat. The cryostat received attention in the Cape Town SAAO instrumentation workshop, a process that was accompanied by valuable knowledge transfer from retired SAAO employee Willie Koorts, who is a cryostat specialist. The SALT team has worked tirelessly on many occasions to ensure that the telescope is operational when these failures occur — a huge thank you to them.

Our Product Lifecycle Management (PLM) process is getting attention to ensure more effective configuration management, especially where change control is required. Moving from an ineffective manual (unmanaged) system to a process-controlled tool will ensure key information and configuration management of the product. Robust information management of the as-built telescope is key to effective maintenance and upgrades. Some of the challenges we had in this reporting period included the availability of spares that were not identified as critical spares during product development. This process, once configured correctly, will assist in minimising this risk of not having the correct spares on-hand in future. We are in the process of hiring a full-time Configuration Manager to manage this process.

The new RSS doublet and triplet lenses were successfully installed during the March 2023 shutdown. While there were some minor tasks during the shutdown, one other main task was to attend to the RSS articulation mechanism in preparation for the RSS VIS detector replacement. The articulation gears were found to be mis-aligned. This gave us the opportunity to verify the current configuration. The RSS long-slits had some setbacks due to supplier manufacturing tolerance challenges. It was with great relief that after the SAAO workshop acquired a high-resolution video measurement machine (capable of measuring 2D profiles rapidly) we were able to manufacture and test the long-slits in-house. After some manufacturing trial runs, the SAAO workshop was able to produce a good quality prototype which was sent to SALT for on-sky verification. Some fantastic feedback from Astro Ops was received recently, prompting us to proceed with manufacturing the remaining batch of long-slits in-house. The Payload Calibration System (CalSys) upgrade design team has formulated a workable conceptual solution, which is being refined currently and shall be tabled to all stakeholders during a PDR in the first half of 2024. The main driver for this upgrade was to extend the bandwidth to 1700 nm for the NIR. At the PDR, the team intends to present the cost/benefit analysis and go through the scope of the work remaining. This will be the basis on which SALT decides if it should proceed with detailed design and/or procurement of this subsystem.

The RSS Dual (MaxE) opto-mechanical designs were presented to the STC to demonstrate the progress made to-date, so that the STC could report this to the SALT Board. The system PDR is planned for 2024. The HRS-HS LFC project experienced some setbacks due to problems with the main laser unit. These were resolved by the supplier and the LFC is now expected to be operational by mid-2024. The RSS etalon upgrade project was put on hold indefinitely. This is due to ongoing failures in deliverables by the coating supplier and, subsequently, the departure of our postdoc, who was assigned to this project. Naturally, science priority had also contributed to the decision to put this project on hold. Some challenges with NIRWALS had delayed the planned commissioning somewhat. This is a new instrument and a steep learning curve for many, but considerable progress was made in 2023. Some gremlins popped out when power interruptions occurred due to Eskom's load shedding schedule. These were quickly mitigated, and NIRWALS is now running smoothly through the intermittent power cuts. Software development of the detector and controller HMI has made significant progress, with the instrument now undergoing on-sky calibrations.

The primary mirror segment recoating schedule has experienced some delays due to technical downtime requiring the telescope to be in its maintenance position on many occasions. The coating plant currently achieves a coating quality of between 85 and 90% reflectivity. We are currently planning the replacement of the diffusion pump (high-vacuum pump) of the coating plant, which will improve the efficiency (the time it takes to coat a mirror segment), and, to a lesser degree, the quality of the coating. A primary mirror database is currently being planned, which will capture important metrics of the primary mirror coating process, with the main purpose being consistent quality monitoring.

Personnel

Jonathan Love, who was one of the longest serving mechanical technicians at SALT in Sutherland, resigned in July 2023 to join SARAO. Alrin Christians, our Mechanical Designer, who had joined SALT for the second time a couple of years ago, also resigned and relocated to the Netherlands in May 2023. They will be missed, and we hope to fill these positions soon.

We welcome our new staff:

- Anita Jonker (Junior Software Developer) started in March 2023

Interviews for an additional new software position were concluded at the end of 2023, with the final round of interviews expected in early 2024. In addition, Malcolm Scarrott is assisting the team to attend to 'efficiency improvement' tasks that we would not otherwise have had capacity for. Former Software Team Leader Janus Brink is assisting the team remotely from Vienna, while day-to-day operations are managed by the new Software Team Lead, Anthony Koeslag.

Health and safety

On a winter day in July, Willem van der Westhuizen slipped on a piece of ice when he was flushing out dirty water from an outside valve after the water had been shut off for a while. He slipped and fell backwards. His elbows absorbed most of the fall, but his head also hit the paving.

No other injuries of staff occurred during the reporting period.

OPERATIONS:
Instrument news

The Big 5 – progress on the RSS upgrade

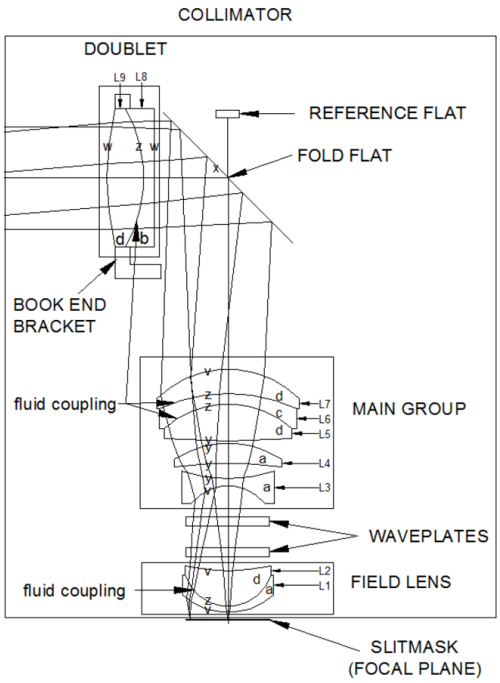
Of the RSS "Big 5" projects that were defined some years back, we are happy to report that three of those five projects are now complete. The PG0700 grating was commissioned towards the end of 2022, and has since been used by several users. The new doublet and triplet were also successfully installed in March 2023, and we have since verified that the troublesome RSS scattered light has disappeared! That leaves the new long-slits and the new detector as the outstanding RSS upgrade projects. A brief status report is provided here.

RSS collimator doublet and triplet installation

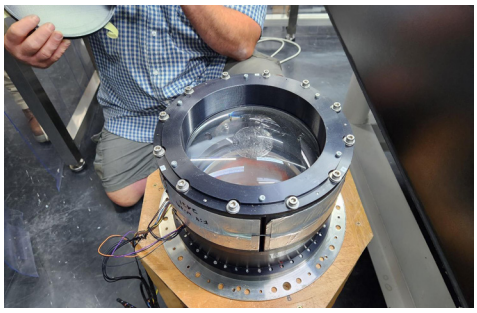
It is with great satisfaction that we can report on the successful installation of two brand new RSS collimator lens groups during an RSS shutdown that ran from 27 February to 31 March 2023. The doublet consists of two lenses (L8 and L9), made of calcium fluoride (CaF_2) and fused silica, while the triplet, which forms part of the collimator main group, includes a sodium chloride (NaCl) lens (L6) sandwiched between two CaF_2 elements (L5 and L7). In order to replace the triplet, the main group needed to be disassembled and the slight changes in the optical prescriptions of the old and new units required careful machining of new shims to precisely align the various elements.

Both the doublet and triplet are fluid-coupled, which means the narrow gaps between the lenses are filled with an index-matching fluid that helps to reduce reflection losses at the surfaces. This lens fluid poses considerable challenges, along with those associated with the particularly fragile lens materials. The NaCl lens, being a large crystal of table salt, is highly sensitive to moisture, while the CaF_2 lenses are vulnerable to thermal shock. In short, dealing with these lenses requires extreme vigilance to avoid either fogging the NaCl surfaces (by effectively dissolving the lens!), or having thermal gradients shatter the CaF_2 crystals. The bladders and channels within the lens cells that contain the coupling fluid also need to allow for expansion and contraction due to temperature changes, while not allowing the oily fluid to escape and contaminate the optics. As a result, the assembly and alignment of these complex optical subsystems posed a variety of challenges and called for very careful work within as clean an environment as possible at the telescope.

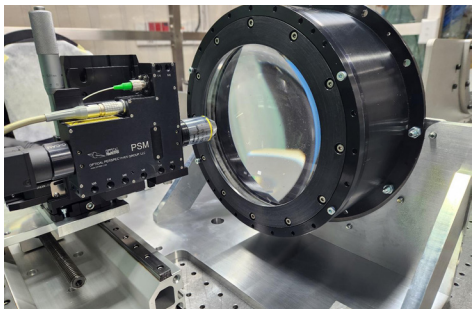
After aligning the new triplet to the singlets, the main group could be installed in the spectrograph and the alignment telescope used to align the various other lens groups to it, including the new doublet.



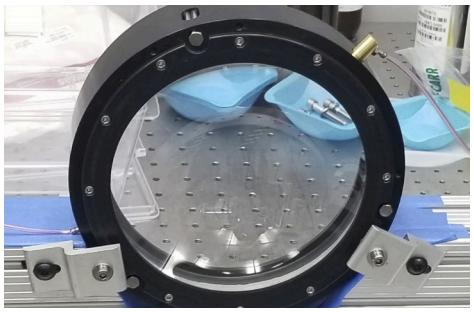
Layout of the RSS collimator optics.



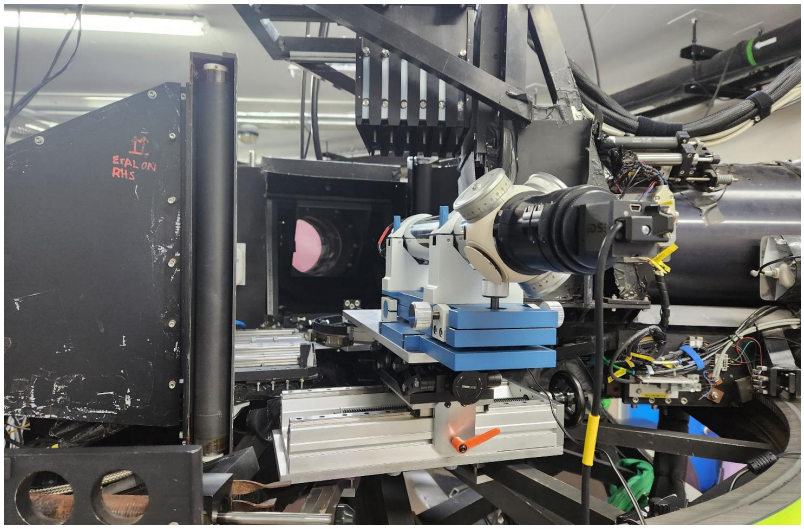
Collimator main group removed from RSS, with an air bubble visible within the triplet.



Measuring the vertex to mounting plane distance for the new collimator triplet.



New collimator doublet.



After all the necessary engineering tests had been successfully completed on the ground, RSS was re-installed on the telescope on 31 March and the on-sky tests began that night. The most eagerly awaited result was that of the scattered light within the spectrograph. This problematic feature, which had been attributed to problems associated with the original collimator triplet, did indeed disappear with the introduction of the new optics. This bodes well for the most demanding use cases for RSS!

Alignment telescope being used to check the alignment of each of the optical assemblies.

The final long-slits are in production

In the last annual report, we discussed the initial efforts to procure sample long-slits from two external suppliers. We concluded that neither supplier could reach the level of precision that we needed. In the past year, we have been working closely with the SAAO mechanical workshop to see what could be done in-house instead.

The first set of SAAO-cut long-slits (1.5” and 2” x 8’) were tested on-sky in August 2023 and showed remarkable promise. It was immediately obvious from inspection of flat field frames that the new samples were a significant improvement over the existing slit-masks. This was also evident from the slit-view frames (see Fig. 1), with no visible defects along the slit edge and increased reflectivity of around 20%. However, it is obvious that our existing 2” slit (top left) is wider than the newly cut 2” slit (top right). This was also evident from the resolution of arc lines. After a bit of head scratching, we discovered that the settings used to cut the new slit masks were not quite right, and they had in fact cut the slits slightly narrower than desired.

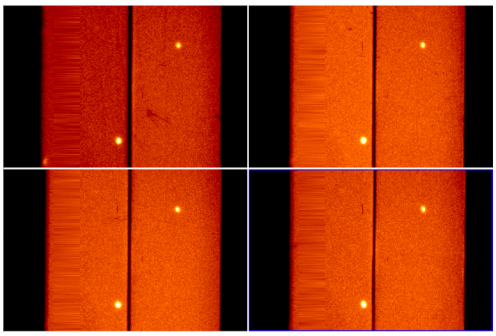


Figure 1: Slit-view of the three sample long-slits, compared to the existing 2” long-slit (top left).

This was quickly corrected and a second set of samples were cut and sent to the telescope for inspection in October 2023. At that time, we had BCAM installed because of emergency repair work to SALTICAM, so it was very difficult to assess the quality of the new samples in slit-view images. The arcs and flats, however, showed excellent results and also told us that the long-slit production process was repeatable at a very high standard. Engineering tests by Tech Ops also showed the samples exceeded our initial requirements for straightness, flatness and reflectivity. Everyone was happy! Some of you may have noticed that your data has already been taken using one of these new masks!

With one final adjustment to the manufacturing process just before the Christmas break (to make sure that all long-slits are cut to exactly 8’ in length, and all polarimetry masks to 4’ in length), we were ready to start cutting our production set of new masks. The first mask (3” x 8’) has very recently been verified at the telescope and looks good, as can be seen from the uniform flat field frame in Fig. 2.

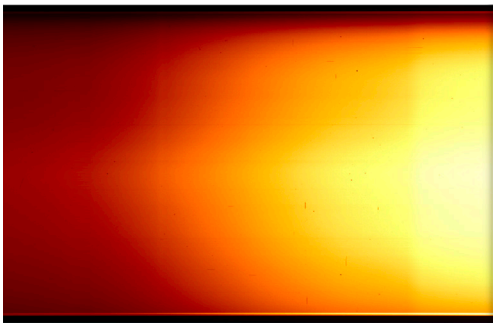


Figure 2: Flat field frame using our first production long-slit (3” x 8’).

At the time of writing, we have the 1.5” and 2” long-slits in Sutherland ready to be verified on-sky. The SAAO workshop is busy cutting the next batch. We plan to have a complete set of long-slits and polarimetry slit masks ready by the new semester.

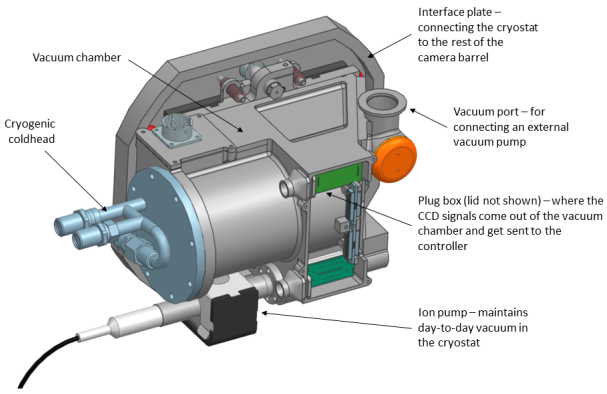
The new detector

The development of the new RSS VIS detector and the planned RSS Red detector on the MaxE project go hand in hand, with development occurring in parallel to accommodate both instruments and take advantage of the commonalities between them. Given an unfortunate cryostat leak on RSS towards the end of the year, expertly patched by SALT Tech Ops in conjunction with retired staff, development focus heavily shifted towards the completion of the VIS detector to mitigate against the risks presented by the existing ageing cryostat.

A technical review to the SALT STC in November presented the development of the mechanical design of the cryostat, the alignment methods and capability, and installation jigs and tools. This provided a good opportunity for technical feedback, which was given and received positively. Remaining work involves finalising the electrical interfaces and layout on the cryostat (in conjunction with IUCAA). This will enable an advanced development model to be manufactured later in 2024, which will be used to qualify installation and alignment procedures, electrical interfacing, and thermal models.

On the CCD controller front, SALT, SAAO, and IUCAA have committed substantially to bringing IUCAA on board as full project team member, an arrangement which is already bearing fruit in terms of IUCAA's input to the detector electronic design and assistance with software implementation and setup. The agreement sees the IUCAA development team assume responsibility for integration, setup, and commissioning of the CCD controllers for the RSS detectors. A controller-specific review is planned for the first half of 2024, followed by an Integration Factory Acceptance Test in the third quarter of the year.

The appointment of Kgomotso Makolomakwe to the SAAO Instrumentation division saw the development of a Programmable Logic Controller (PLC) solution to handling and processing detector system data. The solution provides the ability for one PLC to cater for one or both detector instruments, optimising for mass, space, and energy requirements.



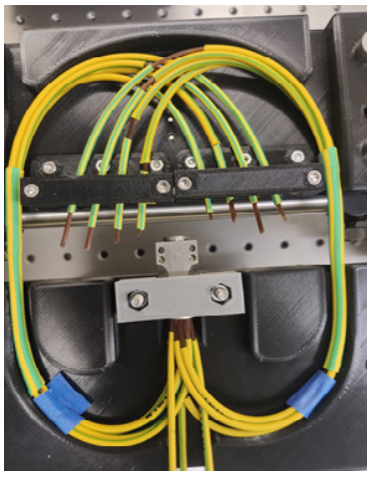
General arrangement of the VIS detector cryostat.

Slit mask integral field units for the RSS

The astro-photonics lab at SAAO is excited to announce that the first of the two slit mask IFUs (SMI) for the RSS is ready to go on sky. The name refers to the compact IFUs (with short lengths of fibre and array of small fold prisms) being housed within a modified version of an RSS long-slit mask. The project started in 2020 when the astro-photonics lab workspace was furnished. During the development phase of the instrument, the lab has been equipped with multiple stations for polishing, assembly, inspection and verification, all of which was necessary to develop the SMIs. The smaller, 200-micron fibre IFU (named SMI200) with 309 x 0.9" diameter spatial elements covering an elongated hexagonal footprint of 18" x 23", is now available for on-sky testing.

The SMIs are inserted in the same fashion as the existing long-slit cassettes at the SALT focal plane. Prismatic fold mirrors direct the focal plane into the IFU and then back into the RSS collimator after the fibres are routed 180 degrees within the cassette and formatted into a pseudo-slit. Fold-prisms ensure that the spectrograph collimator continues to see the same focal plane. The fibres are fanned in the pseudo-slit to mimic the telecentricity of the SALT focal plane as seen by RSS. In the actual focal plane, the central IFU fibres are not fanned, but the sky fibres are to match the range of non-telecentric angles seen by the IFU. This detail is relevant to minimise focal-ratio degradation (FRD) effects.

Given the short length of fibre, transmission losses within the fibres are negligible even in the far-blue. While the prisms have been AR-coated, the fibres are not, so there are two air-glass surface-losses of roughly 3.4% each. In addition, the fibres degrade in the input beam profile (FRD), such that the RSS collimator becomes slightly overfilled. Although the median absolute throughput delivered by SMI200 is 78%, the combination of the aforementioned effect would mean the RSS would collect only 75% of the light delivered by SMI200, which leads to 58% median relative throughput. The final relative throughput values are very similar to Gemini IFUs, even though the latter has significantly less space constraint compared to SMI200. However, the scrambling properties of the fibres should minimise illumination variations over a SALT track, improving sky-subtraction performance significantly. Use of separate sky fibres would aid the sky-subtraction as well.



Fibre routing within the cassette.

The elongated hexagonal shape of SMI is ideal for observing galaxies over a range of inclination angles, and can be used to map more extended objects from Galactic [H II] regions, to merging and interacting galaxies, to galaxy cluster cores and strongly lensed galaxies. Additionally, the SMIs can be effective as a photon bucket for low surface brightness observations as well.

Over the first semester of 2024, we plan to perform science commissioning along with delivering a data processing pipeline. In addition to this, we have started fabricating the larger version, SMI300 (with 1.35" fibres covering an on-sky area of 19" x 35"), which will mimic the NIRWALS footprint and spatial sampling. Along with NIRWALS and upcoming MaxE, SMI300 would deliver wavelength panorama from optical to NIR wavelengths at significantly higher resolution, and possibly simultaneously with the addition of a optical-NIR dichroic beam splitter.

NIRWALS commissioning

On-sky science commissioning of NIRWALS was conducted in 2023 and the instrument is ready to begin shared risk science operations in the 2024-1 observing semester.

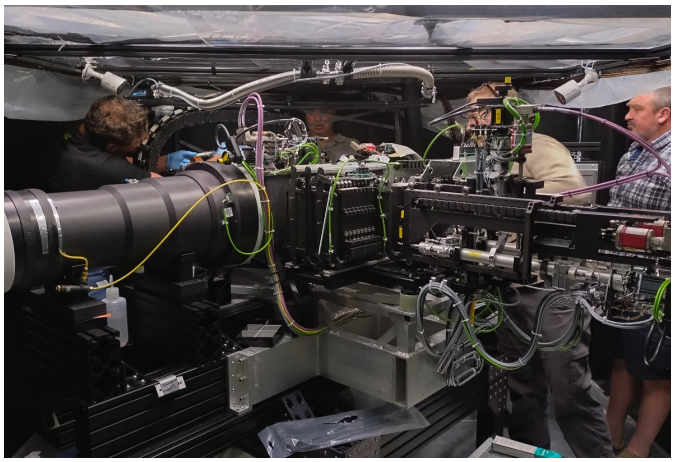
Commissioning was paused from November 2022 through January 2023, while reliability of the SALT facility glycol cooling systems and alarm condition monitoring and reporting were improved to handle the increasingly frequent South African load shedding power outages. These SALT systems are crucial for safe operation of the NIRWALS cooling system. After significant improvements by SALT technical staff, NIRWALS was cooled again in February.

The first task after the restart of commissioning was to investigate the cause of illumination differences between the object and sky fibre bundles that were observed in early commissioning data and rendered the sky bundle much less useful for sky subtraction than expected. Was this due to the positioning of the fibre bundles or the telescope's illumination of the focal plane? Test results indicated that the dominant factor was the SALT differential vignetting rather than the telecentric angles of the fibre bundles set by the fibre instrument feed (FIF). In response, SALT staff have launched an effort to understand and forward-model the focal plane illumination pattern as a function of tracker position, which will ultimately benefit all instruments on the telescope. In the meantime, separate blank sky observations are being used to achieve optimal sky-subtraction in NIRWALS data.

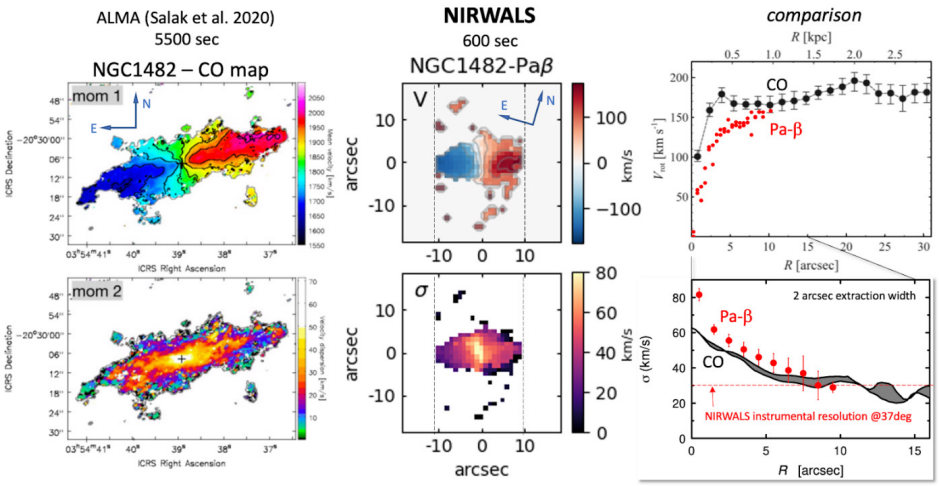
On-sky science commissioning was carried out by SALT Astronomers, in consultation with the UW instrument team, during July through November. These observations tested all performance aspects of the standalone instrument and instrument+telescope. Some of the collected data are still being analysed, but initial results show that NIRWALS is meeting its design specifications for image quality, internal scattered light level, fibre transmission, and configuration repeatability. Total system throughput measured on-sky is consistent with uncertainties in the estimated telescope throughput, which is currently lower than in the past.

In November, two members of the UW instrument team, Michael Smith and Marsha Wolf, conducted a NIRWALS servicing mission to tune up the instrument in preparation for science operations. This work included modifications to the camera focus and articulation mechanisms to increase their reliability at the cold operating temperature (–40^{O} C), installation of an additional long wavelength cutoff filter inside the cryogenic dewar to improve thermal background at the reddest end of the spectral range, and a modification to the fibre bundle mounts in the FIF. These mounts were designed to actively tilt the fibre bundles to the correct telecentric angles as a function of their variable separation distance (SALT field position) to optimise light coupling into the fibres (the telecentric angle on SALT changes quite rapidly with field position). However, non-telecentricity is a second order effect on throughput and cannot be tested until the dominant factor of the SALT focal plane illumination variations are calibrated via forward-modelling. For now, NIRWALS will use the same operational mode as HRS with the object fibre bundle positioned at SALT's field centre and the sky bundle separated at a nominal distance of 97 arcseconds. The sky bundle is now mounted at a fixed angle for telecentricity at this SALT field position.

Work on data reduction pipelines continues as the team learns more about optimising data from the degraded detector. Ralf Kotulla (UW) is developing a Python-based image processing code that removes bias levels of the 32 readout amplifiers, applies pixel-by-pixel linearity corrections, and combines multiple up-the-ramp nondestructive samples during the exposure into a single 2D image. Matt Bershady (UW) is developing an IRAF script that starts with the processed image and does the spectral reduction, including dark subtraction, spectral extraction, wavelength solution, and sky subtraction. This was ported to Python by SALT Astronomer Enrico Kotze. And finally, Python code for generating data cubes from reduced row-stacked spectra is being developed by Antoine Mahoro (SAAO/SALT) and Matt Bershady. A future additional step in the spectral reduction code will be telluric correction using a separate observation of a telluric standard star with each science track. The image and spectral processing codes will become parts of a Python data reduction pipeline that automatically processes NIRWALS data.



Left to right: Etienne Simon (SALT), Nico van der Merwe (SALT), Michael Smith (UW), and Eben Wiid (SALT) removing the dewar for installation of a new filter during the November servicing mission.



Example data cubes produced by Mahoro and Bershady for the ULIRG galaxy NGC 1482. Moment maps (top row: velocity, bottom row: dispersion). The left column presents ALMA CO (J=1→0) moment maps from Salak et al. (2020). The middle column presents the NIRWALS Paβ maps made from a single 600 s exposure. Note the horizontal extent of the NIRWALS data represents the limit of the array (thin dashed vertical black lines). The right column shows the derived radial profiles for velocity (rotation curves) and dispersion. An inclination of 76.1 ± 2.4 deg is adopted to deproject velocities. While the Paβ shows the ionised gas is rotating more slowly at small radii this is expected from its higher velocity dispersion, seen in the bottom row. The CO and Paβ are dynamically consistent with a common circular speed as a function of radius; this demonstrates the ability of NIRWALS to make accurate and precise kinematic measurements.

Laser frequency comb development

Considerable progress was made towards completing the integration of the laser frequency comb (LFC) for SALT's High-Resolution Spectrograph (HRS) during 2023. The LFC is a state-of-the-art wavelength-calibration device that will equip the HRS for highly demanding precision radial velocity studies, such as those used to search for and characterise exoplanets.

Astrocombs tend to be extremely complicated and prohibitively expensive systems. Rather than simply contracting Heriot-Watt University (HWU) in Edinburgh to build and deliver a comb for SALT, we are working collaboratively so that the assembly and integration take place at the telescope. This affords SALT staff and students a fantastic opportunity to participate in the development of an LFC that is specifically tailored to suit our HRS.

The action started in early February when Richard McCracken, HWU laser physicist and technical lead for the project, visited us in Cape Town for four days. With all of the major components having been ordered and delivered to our lab and/or manufactured by the SAAO workshop during 2022, by February it was time to check that everything fits and works. This very short trip served to identify issues that could possibly impact on the integration and installation of the comb that was scheduled for later in the year. The timing of this brief visit was ideal as a group of enthusiastic interns got to spend time with Richard and engage with the fascinating LFC hardware. A few minor technical issues were addressed and one component (an acousto-optic modulator unit) was found to be unsuitable for our purposes, so an alternative (an electro-optic modulator) was ordered. Given the relatively long lead-time for the EOM, Phase I of the integration campaign was delayed to the first week of August.

Prior to the LFC team's arrival, members of the Tech Ops team reorganised the HRS electronics room to prepare the space for the astrocomb installation. All of the hardware was also transported up to SALT and carefully packed and sorted in anticipation. Having flown all the way from Edinburgh (via London) and then spent another five hours in a car, the intrepid laser physicists (Richard, and postdoc Shan Cheng) somehow still found the energy to get started on their first evening at SALT!

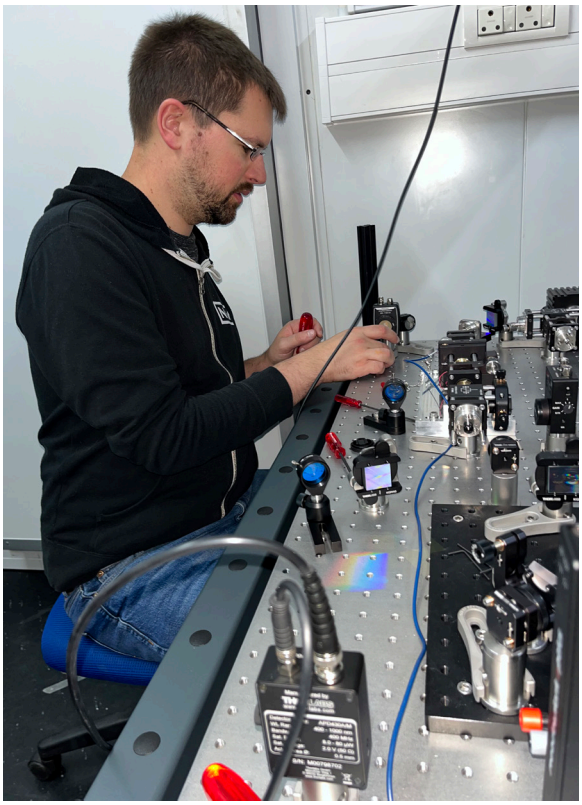
The ensuing week was a fascinating blur of lasers, countless optics and various electronic devices as the team assembled, aligned, tested, re-aligned and re-re-aligned the various modules that will make up the LFC. The system's main titanium-sapphire laser again gave us a good scare when it suddenly refused to work. But after getting permission from the UK-based supplier to open up the controller unit, a bad connection was soon found and fixed. Then the manufacturer's laser techs were able to connect to the laser unit and tweak various parameters (including dialling up the pump laser's power from 11 to almost 12 W) to get it to wake up reliably. We also tested the single-mode fibre that had been left behind at the end of the LFC field trial at SALT back in 2016 and were relieved to find that it still works. This allowed us to briefly inject some faint super-continuum light into the spectrograph on the last evening of the campaign. While the resulting image was not objectively spectacular, this was a huge milestone to reach in such a short period of time!

In addition to all the beautiful mechanical parts produced by the SAAO workshop team in Cape Town and the enthusiastic support from SALT Tech Ops at the telescope, we also leaned heavily on countless people in Sutherland and Cape Town to help us out during this crazily busy week. By the end of the run we had a long to-do list to address ahead of the HWU team's return, including a couple of parts to remake and/or modify, and things to order to complete the building of various electronics boxes needed for the different locking loops. As with Richard's brief Cape Town visit in February, this trip was hugely productive, instructive and enjoyable.

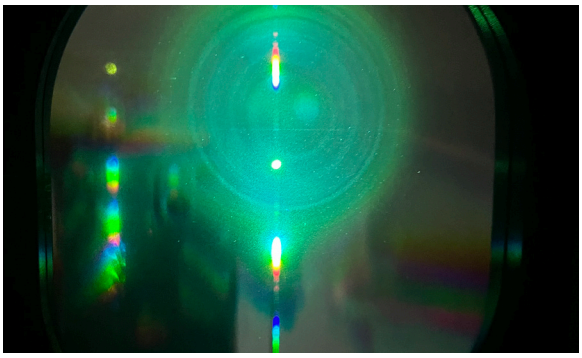
At the end of November, Richard and Shan arrived back in Cape Town, and we again blasted straight up to SALT to resume the laser comb integration that had started in August. Many more parts had either been delivered, modified, or completed in the time since, and the two of them hungrily fell upon the components, eager to get all the systems going. The main titanium-sapphire laser again needed some remote attention from the vendor in the UK, but all the other equipment performed well. SALT software developer Malcolm Scarrott quickly set up a software interface for the new frequency counter, and the new mounting blocks made in the SAAO workshop a few months earlier greatly simplified the alignment of the photonic crystal fibre. A gorgeous, and remarkably powerful super-continuum (a brilliant array of individual laser spots that blur into a red-through-greenish spectrum) was promptly generated — a big relief after the difficulties experienced back in August.

Working at least 14-hour days, there were some ups and downs along the way, but overall progress was being made at a good pace. Derryck Reid (also from HWU) and our pipeline developer for the high-stability (HS) mode of the HRS, Daniel Holdsworth, joined us at SALT during the second half of the 12-day campaign. The remaining time was again packed with optical alignments, tinkering with electronic locking loops, and hacking together various software interfaces to get all of the equipment to be controllable from the dedicated comb laptop. With just a few days to go, a firmware update to the main laser went awry and suddenly neither the vendor, nor the LFC team, could access or control the laser at all. This was a major blow given all that was planned for the remaining days, though the team still made productive use of their time on site and the laser vendor resolved to send us a physical dongle with the necessary software onboard to regain access to the laser. Although this did not happen within the 2023 calendar year, we are relieved to report that the issue had indeed been resolved by the time this annual report was written!

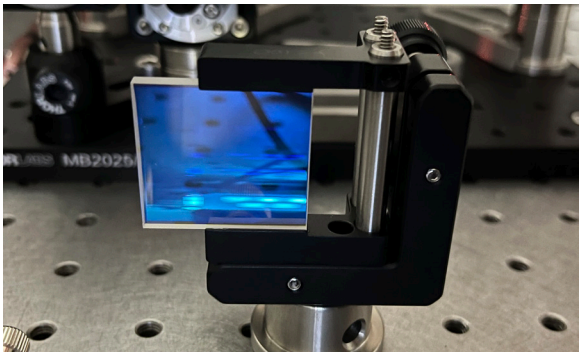
Richard and Shan plan to return again in April 2024 to pick up where they left off, but there is plenty of work to do in the meantime, including running more HRS stability tests and putting more software tools together to interface with the various devices and subsystems. We eagerly await the next phase in the integration process, which will be followed by lab and on-sky commissioning of the astrocomb. The HS pipeline development continues in parallel and we hope to begin gathering science verification data during the latter part of 2024.



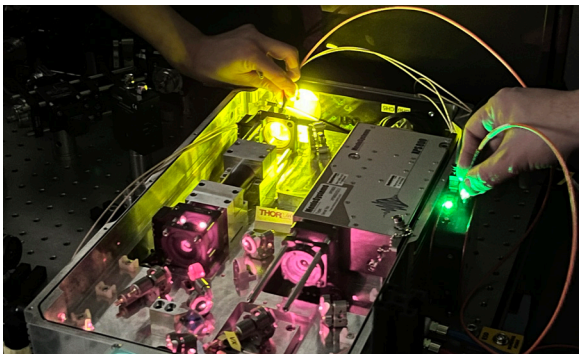
Richard McCracken from Heriot-Watt University aligning optical elements on the LFC bench.



Using an old diffraction grating to view the super-continuum spectrum.



A cylindrical lens that forms part of the spectral flattening unit of the comb.



Light form the Ti:Sapphire laser (pink) being transformed into a super-continuum (yellow), with some light being fed into a compact spectrometer (next to the green LED).

DIMM upgrade

In the second half of June, former SALT Astronomer Timothy Pickering, now at Steward Observatory (USA), visited to perform some hardware upgrades to the seeing monitor system, TimDIMM. The most significant upgrade was to replace the camera used to measure the seeing. The new CMOS camera features significantly less noise (2 e^- *vs* >25 e^-), faster readout (300 frames/sec with a 400 x 400 region-of-interest), greater dynamic range (12-bit *vs* 8-bit), and higher quantum efficiency (>80% peak *vs* ~40%). The new camera also uses a standard, readily available USB3 interface instead of the now-obsolete IEEE1394 interface the previous camera used. A second CMOS camera was added to the system as well to work as an acquisition camera along with a new 50 mm guide scope.

The telescope with the new seeing camera at the bottom and the new acquisition camera to the right (both in red).

Upon arriving in Sutherland, the new cameras and finder scope were easily attached and ready to test. Unfortunately, once on-sky it was apparent that the TimDIMM's mount was not healthy at all and its tracking performance was quite poor. It was also apparent that the field-of-view for the seeing camera was limited by the aperture within the MASS-DIMM instrument, rather than by the camera itself.

The mount was taken apart and refurbished to the extent possible, and although this did improve the tracking performance somewhat, the system was still significantly degraded. We hoped to work around this by employing a wider field-of-view, restricting the system to only use southerly targets, and limiting seeing measurements to ~15 seconds.

To achieve the wider field-of-view, the MASS-DIMM instrument was removed and the old DIMM mask was installed on the front of the telescope. This reduced the weight of the system (and thus the burden on the mount) and removed a heavy cable wrap that was no longer needed. This cable wrap was also likely snagging the power cable for the mount on occasion, which would cause a power glitch resulting in the mount losing its bearings. The USB cables for the new cameras are also significantly lighter and hang further back, so they will no longer interfere with the mount's power input.

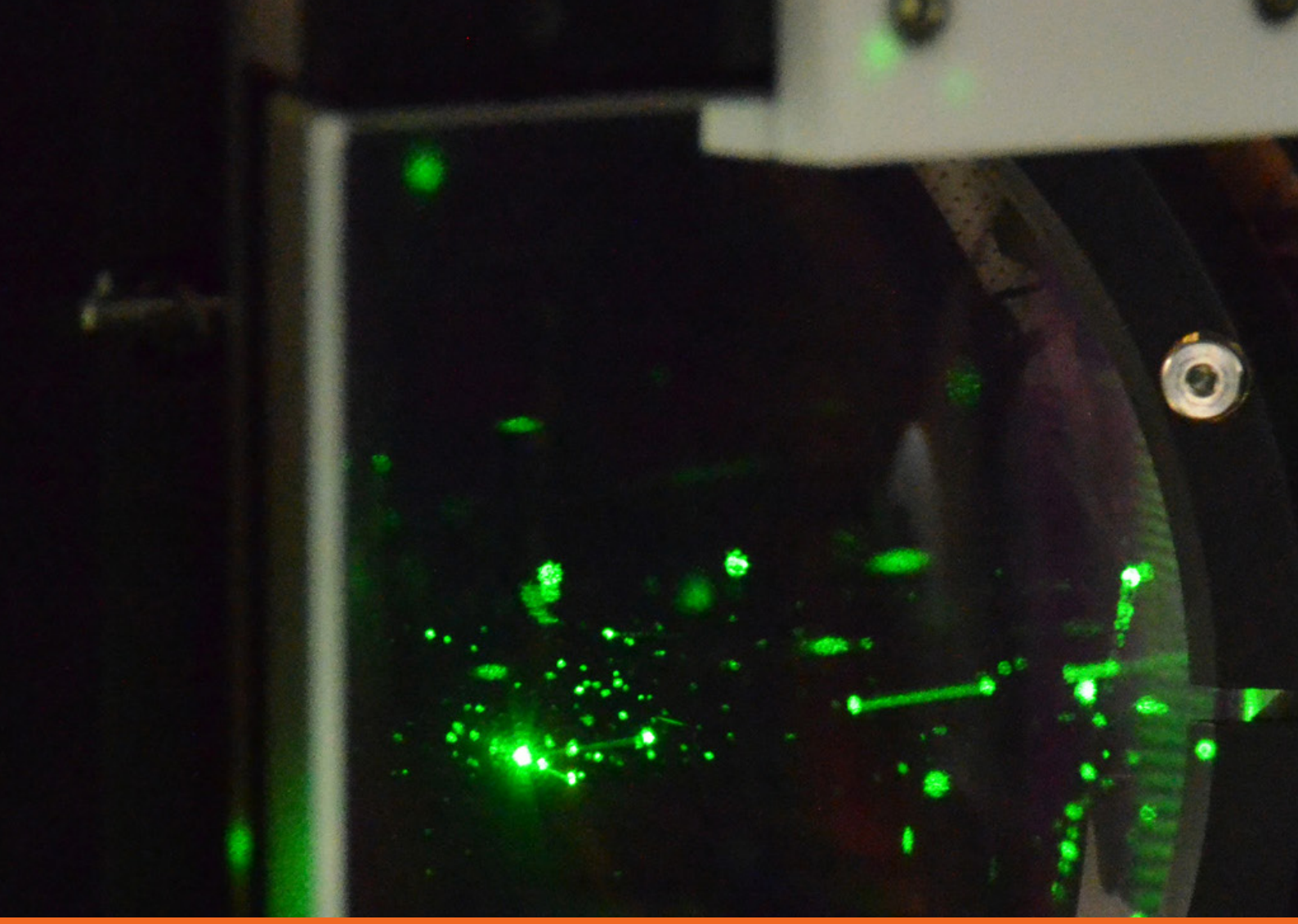
After some manual interventions to align the DIMM mask and the acquisition scope, it was finally possible to do some proper on-sky testing with the new configuration. However, poor weather ensured that this only happened on Tim's last night before flying home in early July. In spite of that, several key things were established:

- Useful seeing data could be acquired using stars as faint as 3rd magnitude with 1 ms exposures.
- The new acquisition scope and camera worked very well for accurately acquiring targets. The 'Align' function in KStars was used to acquire images, measure their astrometry, and then update recalibrate the mount based on the solution. This function iterates until the solution matches the pointing to within 20", which would place the target well within the inner 400 x 400 pixel region of the seeing camera.
- The software to interface with the DIMM enclosure was updated to Python 3 and successfully migrated to a new computer.
- The tracking issues hinder the ability to observe northern targets, but are much less of an issue for stars south of –30° declination.

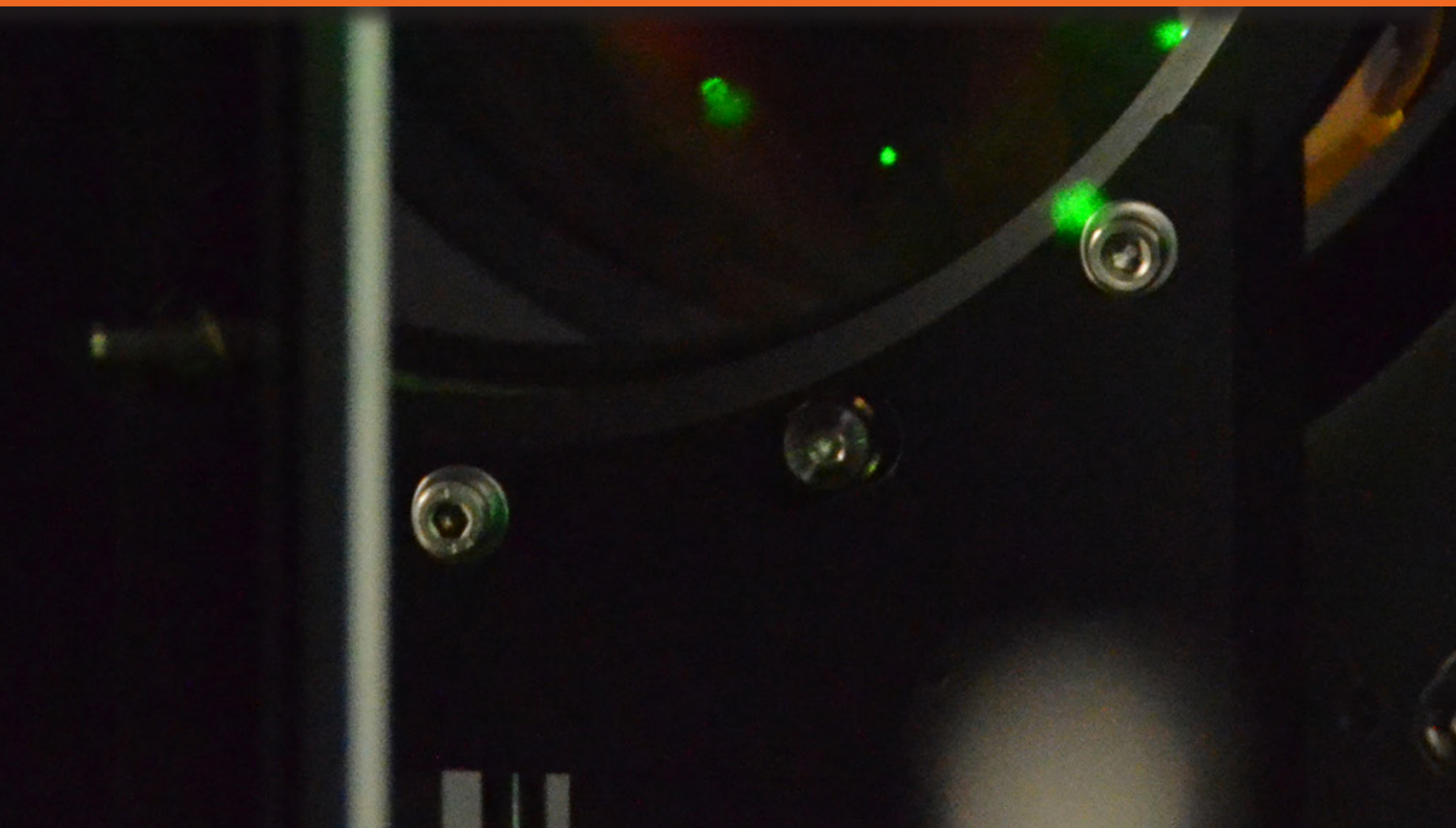
While there was still software work being done to finish the job, it became clear in late August that the telescope mount had become unusable, producing spurious signals that would render reliable remote operation of the system impossible. Thus it was time to order a new mount, which would take 2 – 3 months to arrive in South Africa.

Happily, the beautiful new mount did arrive safely at the end of November and work was soon underway again to complete what had evolved into a far more extensive upgrade. Various travel commitments, year-end holidays and unseasonal bad weather in Sutherland led to further delays, but we look forward to having the system in fully-automated operation within the first few months of 2024.

The recently arrived new mount.



OPERATIONS:
Software updates



Significant effort is required to change the existing **RSS detector** (PDET) software to support the new detector controller of the RSS VIS upgrade project. A re-design of the detector software is currently underway. A development plan has been drawn up and the requirements specifications are presently being compiled. Part of the upgrade would be identifying software technologies that are not well supported anymore and possibly replacing these with frameworks that have better support in terms of development as well as being maintained by the software teams. The project also hopes to produce detector interface software that is generic and can be adapted to all SALT detectors at present.

A full review of the **communications elements** between the Telescope Control System (TCS) and the subsystems was performed to clean out deprecated items and to ensure the Event Logging System (ELS) is accurately monitoring the health of all subsystems.

The **Guider Pre-Positioning** (GPP) functionality was fine-tuned to more accurately position the RSS guide probes while pointing the telescope based on automatically selected guide stars in the field. The selection criteria of these guide stars were also improved to ensure more efficient acquisition. The addition of FIF guide probe pre-positioning is currently underway.

The **RSS detector software** was updated to solve the issue of FITS headers that could not be populated during frame transfer observations. The solution was to have an independent LabVIEW process on the detector control host that would receive the latest FITS headers from the instrument computer and write them into a text file. The detector code was updated to read the FITS from that text file and update the FITS headers in a frame transfer FITS file. To avoid reading outdated information, the FITS headers from the text file are only used if they were updated within the last three seconds. This code was only updated for the frame transfer mode and does not affect other modes. Updated software has been tested and deployed, it is now waiting to be verified with the next frame transfer observation.

Progress is being made on the **Structure and Dome Control (SDC) upgrade**. A Programmable Logic Controller (PLC) has been added to interface between the main software application and the hardware (inclusive of sensors and actuators over the SALT profibus network). The main application has been moved to an Industrial PC, and will communicate with the PLC via the OPC Unified Architecture (OPC UA) communication protocol and profinet. All the control functions that are currently performed in the main control application have been moved to the PLC for improved robustness. The SDC main application now interfaces between other telescope subsystems, the SDC user interface and the PLC. Development and testing on the main application and the PLC software is continuing before deployment on the live system.

Telescope pointing and focus

The pointing model calibration performed in 2022 remained stable and robust during normal operations. A re-calibration on-sky was performed in July 2023 and has been stable since. The telescope pointing and acquisition location was changed to be at the rotation point of the Tracker Rho stage as this defines an easily measurable reference on both SALTICAM and RSS.

The telescope focus model was updated based on on-sky measurements as a function of tracker location. This model performs well, but additional systematics based on other effects such as the Structure Azimuth angle and Tracker Rho stage rotation angle are also affecting the open-loop model. Throwing the net wider, a machine learning model has been trained on a wide set of parameters to determine their correlation with the remaining focus error. Implementation of an on-sky test of this model is currently underway.

NIRWALS development

The NIRWALS instrument, developed by our colleagues at the University of Wisconsin, is currently being commissioned at SALT. The instrument expands SALT capabilities by adding spectroscopy within the demanding NIR region of the spectrum. Observations in this spectral range are hampered by atmospheric interference, requiring the instrument to run a dither pattern to move on and off the target to correct for this problem. Furthermore, the spectrograph is extremely sensitive and requires constant monitoring to ensure that the thermal enclosure it is housed in remains at a carefully controlled –40^{O} C.

Instrument control

The instrument arrived with custom developed software, which monitors the instrument and sends out reports at 30-minute intervals. This software acts as an interface to the instrument, which the SALT software team is using to develop the NIR SALT control interface, NCON. NCON makes use of a modular design, allowing for each module to be developed independently by different software engineers. It also facilitates the addition of new modules with relative ease. A practical advantage of developing each module independently is that these can easily be tested independently, meaning that during development a small suite of testing tools are developed along with each module. It was important to ensure that most of the software team was included in the development of NCON to allow the team to be able to maintain the instrument if one of the engineers were to be unavailable.

The astronomer's interface was designed so that the user would have all relevant information on one screen, while having controls for engineering purposes available on other tabs.

As mentioned earlier the instrument is very sensitive, and requires constant monitoring. To ensure this, a redundant monitoring system was developed that detects when the control software shuts down and starts monitoring the instrument from another computer on the SALT network.

The NCON UI was designed in collaboration with the astronomers to, hopefully, simplify the use of the instrument for science observations. As it is required that the instrument will run long patterns of exposures with small payload offsets, via a dither pattern, it is assumed that the astronomers might want to stop a procedure temporarily and then restart from the last run exposure. Allowing for this, each step in the procedure is assigned a 'step tag', and while the procedure is executing, the current step tag is tracked in the control labelled 'start at step tag'. If the procedure is stopped at any time during the procedure, this control will allow the astronomer to start from the correct step seamlessly.

The software architecture that allows for the flexibility described above was developed to allow for complex series of events to be arranged to execute in parallel and series as required. So, a typical procedure will have a series of events such as 'move tracker' followed by 'do an exposure' then 'update the start from step tag', repeating for all the steps in the dither pattern. While simple in nature this architecture allows the instrument to run a complex pattern of events with little user interaction.

TCS / payload changes

The payload software was upgraded to include status monitoring and publishing of the NIR calibration screen status. This allows the selected lamp and other settings of the NIR calibration system to be populated in the headers of NIRWALS data files. Further improvements to the payload software included completion of the TCS control interface for the FIF module. This now allows more robust control from the local FIF user interface as well as support for FIF dither commands from NCON via the TCS.

User support

At the end of January 2023 the new **Web Manager** was released. It is realised as a single page application, written in `Angular` for the web frontend and `FastAPI` for the backend. For large proposals, the page load time of the new Web Manager was reduced by an order of magnitude compared to the old Web Manager, resulting in a vastly improved user experience. Various improvements were added throughout the year (such as a page for SALT Operators and NIRWALS related updates), and the old Web Manager is expected to be decommissioned in 2024. The new Web Manager is available at https://wm-new.salt.ac.za/.

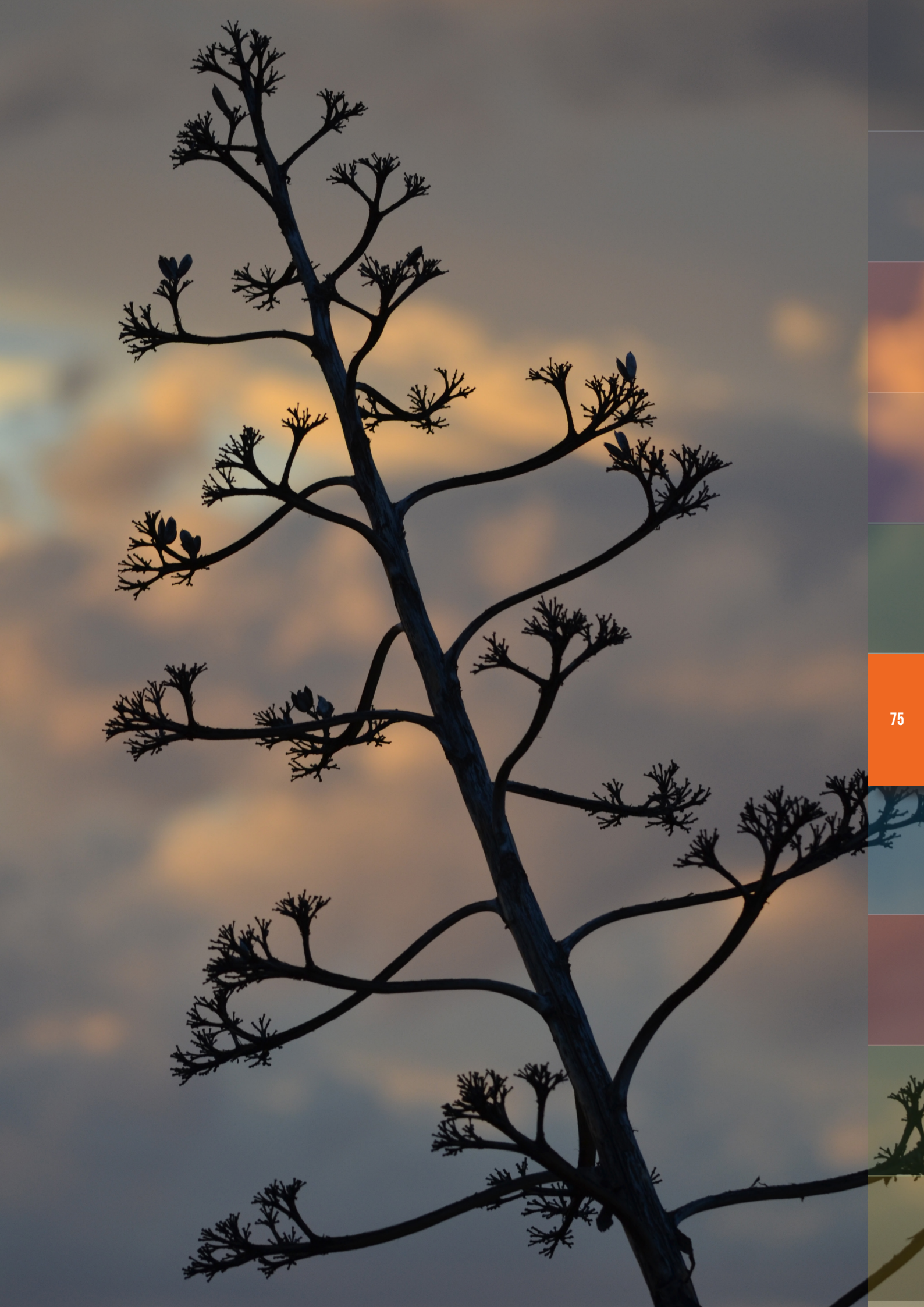
For the 2023-2 Call for Proposals, the new **NIRWALS Simulator** was released as a browser-based application. It can be used to generate plots of the expected signal-to-noise ratio, either as a function of wavelength or as a function of exposure time, for a variety of spectra. The calculations make heavy use of the `synphot` library. The NIRWALS Simulator can be accessed at https://simulator.salt.ac.za/.

Important changes were made to the code base of the **PIPT.** The XML schema used for validating proposals has been significantly simplified, paving the way for the ability to submit proposals as JSON rather than XML in future. The new XML structure will also improve the overall robustness of the PIPT code. Other updates include changes required by NIRWALS commissioning proposals.

The new online **Finder Chart Generator** adds the capability to generate finder charts for NIRWALS observations. It also allows users to add a reference star to the finder charts, as well as to calculate the required position angle from that star. The user may also upload their own FITS file, in particular if they need a zoomed in finder chart. The Finder Chart Generator is available at https://fc.salt.ac.za/.

To enhance the functionality and security of the Web-based **SALT Astronomer-Machine Interface** (WebSAMMI), its code was updated to utilise the latest libraries and address identified vulnerabilities. Additionally, the code was modernised to ensure compatibility with contemporary container environments.

The Astro Ops software team: Christian Hettlage, Chaka Mofokeng and Nhlavutelo Macebele (from left to right).



OUTREACH AND EDUCATION

OUTREACH AND EDUCATION:
SALT Collateral Benefits Programme

The SALT Collateral Benefits Programme (SCBP) was established during the construction of SALT, with the objectives of this programme being clearly directed at the benefits derived by society from building this large telescope. Its focus points are education in mathematics, science, engineering and technology; science communication and awareness; socio-economic development, and public engagement. Today, the SCBP activities are run by the SAAO science engagement personnel.

2023 has been a prosperous and successful year for the SCBP, as the team, with the support of SAAO staff, continued to implement science education, science communication, science awareness programmes and Sutherland community development and support initiatives. We continue to relentlessly communicate the beauty, relevance and power of astronomy through the development of tangible programmes, geared towards reaching various audiences including school based learners, teachers, university based students, girls and women, media, indigenous knowledge holders, science centres and the general public. A total of 23 349 people were reached and engaged in teacher training and support programmes, curriculum based learner activities, extra-curricular learner activities, job shadow and career programmes, collaborative outreach programmes with other organisations and institutions, day and night tours, science capacity building programmes, open nights, stargazing sessions and public lectures.

Teacher training, support and development

As SCBP, we believe that empowering and inspiring teachers is fundamental and a key to improving classroom practice and appreciation of the value, relevance and power of mathematics and science. Consequently, we continue to facilitate teacher development and support workshops that are intended to improve teacher content knowledge, attitudes and pedagogical knowledge. We always strive to share relevant and quality astronomy related content, innovative and creative pedagogical approaches like hands-on activities, computer based simulations, use of models, direct observation of the sky and internet based activities.

In 2023, the SCBP teacher development and support team, consisting of Buzani Khumalo and Sivuyile Manxoyi, concluded a series of intensive teacher training, support and development workshops based on the theme “Earth and Beyond” in the following provinces: Eastern Cape, Western Cape, and Gauteng, reaching 667 teachers.

The first set of workshops was implemented in collaboration with the IAU OAD office on 28 February. The workshop was based on the “Pale Blue Dot” resource material developed by the IAU Office for Astronomy Education (OAE) and involved eight primary school teachers. Since 2023 has been declared the year of education for sustainable development by UNESCO, the Pale Blue Dot programme seeks to use astronomical content and -linked problem solving skills and activities to connect STEM topics with the sustainable development “Working with the Association for Education Transformation (ASSET)”. Another two teacher based sessions were held at the Zandvliet Secondary School and Walacedene Secondary schools on 11 March, reaching 41 and 38 high school teachers, respectively. These sessions were based on using astronomy as a context for teaching mathematics and physical science (a subject consisting of physics and chemistry in South African schools).

Working with the Eastern Cape Department of Education, the second set of teacher workshops was held in the rural towns of Sterkspruit and Aliwal North from 19 – 21 September, reaching 94 teachers. The workshops focused on the senior phase of natural science and covered topics such as seasons, tides, telescopes, the solar system, galaxies and the birth and death of stars. We were quite impressed with the knowledge, expertise and experiences of the Aliwal North teachers, where some of them shared the challenges that they encounter, in particular, that of teaching the phases of the moon and the reasons for the seasons. The conversations, questions and follow up discussions were quite enlightening and beneficial to all the participants.

This was followed by a joint full-day teacher workshop held at the SAASTA offices in Pretoria on 4 October. It focused on 32 teachers for Grades 8 and 9 at schools in Limpopo and Mpumalanga. Aside from delivering the prescribed knowledge content, we sought to provide relevant examples of how astronomy could be utilised as context to demonstrate the application and relevance of physical science and mathematics content.

The SCBP team shared their experiences of working with teachers at the African Regional Shaw-IAU Workshop on Astronomy for Education, held at SAAO on 3 – 5 October. Their presentations were a cross section of what they have learnt from teacher based workshops. This included a reflection on misconceptions and alternative conceptions. The participants considered direct observation (using the sky as a resource), the use of models and hands-on activities, use of relevant software and of telescopes (including remote and robotic telescopes), storytelling and drama.

The last phase of the workshops took place from 10 – 12 October. This was a collaboration with the Western Cape Education Department (WCED), and all the workshops were held virtually. More than 500 participants were drawn from towns and cities of the Western Cape. The Cape Town Science Centre provided the relevant set up, including microphones, camera and screens, to ensure delivery of an effective and successful workshop. Representatives of SARAO and SANSA were Simphiwe Madlanga and Thandile Vuntu, respectively, who covered aspects related to their facilities, namely MeerKAT and micro satellites, respectively.

The collaboration was a great success and went beyond expectations. The workshops covered all prescribed content for Grades 4 – 5 on the first day, Grades 6 – 7 on the second day and Grade 8 – 9 on the third day. The positive feedback via email from the teachers as well as the curriculum advisers emphasised this. For the next financial year, the WCED intends to send all natural and physical science curriculum advisers to Sutherland for a week to experience the beauty of the dark skies, visit SALT and other telescopes on the plateau and also appreciate the impact of big telescopes such as SALT on rural towns and communities.

Learner activities

The SCBP learner based programmes include curriculum aligned activities such as lab based workshops, co-curricular activities such as the astronomy quiz and astronomy debates, and extra curriculum programmes such as career info based activities, robotics, holiday and girls focused programmes. In 2023, 10 042 learners were reached this way.

An **SCBP–Dartmouth College** joint education and outreach programme was implemented in Cape Town and Sutherland between January and March. A group of Dartmouth physics and astronomy students led by the Chair of the SALT Board, Brian Chaboyer, joined the SAAO education staff and implemented a programme that included curriculum aligned activities, career discussions and demonstrations at various Cape Town schools. Learners from Aloe Junior in Mitchells Plain (384), Kulani High school in Langa (57) and Zisukhanyo in Samora Township (40) participated in the programme. At Sutherland, the Dartmouth College group collaborated in similar activities at the two Sutherland schools Roggeveld Primary and Sutherland High School.

The SCBP team collaborated with **NSF-linked astronomers** from the USA (Amanda Sickafoose, Sanlyn Buxner and Mark Lewis) in the implementation of astronomy activities at the Summerdale High in Mitchells Plain on 24 April. The presentation and activities were based on the solar system and reached 39 learners. This collaboration intended to produce various materials for teachers and for learners based on the astronomy content in the SA curriculum. Buxner also gave a talk at one of the open nights as well as a colloquium to SAAO's postgraduate students and scientists.

Tomorrow Trust, a non-profit organisation based in South Africa, provides support to orphaned and vulnerable children throughout their journey with holistic education academics, life skills, self-development, and support to help balance life aspects of the student's mental and physical health. They collaborated with SAAO by organising a visit to SAAO for 20 Grade-11 learners on 9 October. They were given a presentation on mental health by Dominic Vertue from IAU-OAD, a site tour by SALT software engineer Christian Hettlage, and a telescope workshop by education assistant officer Cedric Jacobs. The success of their visit is captured in their resolution to continue visiting SAAO on an annual basis using a similar programme but different sets of learners each year.

Angel Community Outreach is an organisation that aims at the poorest of the poor by assisting with youth development and offering educational and arts programmes. They collaborated with SAAO on the implementation of a science engagement programme for 42 Grade 3 – 8 learners. This was held on 21 October and consisted of presentations on the solar system, telescope and binocular workshops, and site tours.

The SCBP effort to develop an **inclusive outreach and engagement programme** continued with education officer Buzani Khumalo delivering a programme at the Dominican School of the Deaf on 26 October. A total of 46 learners participated in telescope building and a solar system presentation. This is part of SCBP's efforts to also engage members of the public with various disabilities, including the blind and the deaf.

An **astro-art competition** for the foundation and intermediate phases, which started in October 2022, was concluded in January 2023. It attracted 4392 entries from primary schools in the Western Cape and Northern Cape provinces. The competition encouraged the learners to express their conception, perception and impact of astronomy and space on their lives through artistic creations and products. Four prizes were awarded for each of the two categories, the foundation and intermediate phases.

The Rising Star Tutoring project

A Grade 12 physical science tutoring project named “The Rising Star” was launched on 3 February in collaboration with the Thandokhulu High school located near SAAO in Mowbray. This is an after-school tutoring project aimed at improving the physical science performance at the school by providing extra classes, creating opportunities for learners to complete some exercises based on the curriculum content, and by creating space and opportunities for learners to raise questions to clarify their studies. The tutoring sessions are held on a weekly basis on alternative Wednesdays and Thursdays. The tutors are drawn from SAAO staff, post graduate students and volunteers from the UCT faculty of science students.

Implemented in 2023, this first year has already delivered excellent results as all the 61 learners in mathematics and science have passed (100%), with the top learner obtaining 97% at the physical science final examinations. The excellent results have enabled all the learners to pursue science and engineering studies at various institutions, with the top student registering for actuarial science at UCT. The programme will continue in 2024.

Career-based activities

The career based programmes serve to disseminate information on various science and technology based careers, introduce the learners to role models, and generally inform and inspire learners about the relevance and significance of science based studies on development and society.

The job shadow programme

2023 was an awesome year for the SAAO Job Shadow programme as we returned to full capacity since the COVID-19 restrictions were rescinded. Thanks to a great team, two sessions were successfully completed, accommodating 29 learners from Grades 10 – 12. As always, the programmes took place during the school holidays, the first on 27 – 28 June, and the second on 3 – 4 October.

The popularity of the programme has grown over the years with learners coming from various provinces (Gauteng, Eastern Cape and North West Province) as well as from in-province places like Van Rhynsdorp, Stellenbosch and Paarl. Both sessions ran exceedingly well, and it was evident how much the Job Shadow team missed interacting with the learners, how much they love their jobs, and how excited they are to share their knowledge and experience. From the programme coordinator’s interactions with them, as well as the indications on their feedback forms, the learners arrived hungry for information, and the SAAO team did not disappoint. They left SAAO fully informed about the various careers covered by SAAO, with many making long-term friendships along the way.

A total of 29 learners participated in the programme in 2023, bringing the total to a whopping 247. We are all immensely proud of what we have accomplished and continue to accomplish through this programme. From the feedback received (though not all the learners respond), over 40 learners so far decided to pursue degrees in Science, with 18 of them studying Astrophysics.

The SAAO Job Shadow programme continues to be a beacon of enlightenment and hope for diverse groups of learners from different schools, areas and backgrounds, all searching for their possible future career paths.

The programme coordinator, Natalie Jones, was also called to assist with a French–South African student for an extra, 4-day job shadow of the SAAO director, Petri Väisänen. It was implemented for the Grade-9 learner in February, supported by post graduates and colleagues from various SAAO departments. The programme provided an opportunity for the learner to interact, observe and engage with various professionals involved in astronomy, engineering and information technology at SAAO.

Career exhibitions and career talks

A SANBI (South African National Biodiversity Institute)–SAAO career based biodiversity education and public engagement programme was implemented at the Karoo Desert National Botanical Gardens in Worcester on 1 March. The programme included presentations, a workshop and dissemination of career based brochures. A total of 57 learners participated in the programme.

The SCBP staff participated in the CHIETA (Chemical Industry Education and Training Authority) career exhibition held in Westridge in Mitchells Plain on 18 March. This exhibition included presentations, exhibition and dissemination of career information. iThemba Labs and SAASTA outreach practitioners were also in attendance and also presented career info to the 680 learners in attendance. Representatives of the WCED, private sector and non-governmental organisations in science education were also present and exhibited.

Working jointly with IThemba Labs and Stellenbosch University, the SCBP team participated at the science career exhibition held at the Thembelihle High school in Khayelitsha, Cape Town, on 13 April. A total of 369 high school learners participated in the programme.

The SCBP team, working with the BRICS group, AfAS, SAASTA and various science institutes and organisations, conducted a series of career exhibitions in the KZN province from 15 – 19 May. Areas covered included the towns Kokstad, UMzimkhulu, Jolivet, Pholela and Ixopo. The programme included exhibitions, presentations, dissemination of career information and hands-on activities. A total of 1246 learners participated in these exhibitions.

A further BRICS collaboration including the IAU OAD, delivered a career based programme for Sutherland learners on 7 September, with 81 learners from Grade 8 – 11 participating in the programme.

Girl-focused programmes

A hybrid event, consisting of in-person and online presentations, was implemented at Langa High school on 22 May. This effort was led by the SAAO education officers Buzani Khumalo and Cedric Jacobs. It also involved SAAO astronomers and postgraduate students presenting on astronomy for study, career and research. A total of 24 girl learners participated in the programme. This was a seed programme, intended to blossom and culminate into the National Women's programme in August.

The chairperson of the Parliamentary Portfolio Committee (PPC) on science and technology, the Honourable Nompendulo Mkhatshwa, led a group of 110 Gauteng based girls on a 2-day visit to Sutherland. Inspired by her 2022 visit to Sutherland and SALT, the PPC chairperson requested a programmed visit that sought to expose the girls to astronomy and engineering through the science and technology of SALT, appreciation of the dark skies and indigenous astronomy, and astronomy effects on mental health. The group was in Sutherland on 27 – 28 July. The programme was a great success and was appreciated and shared on various platforms by members of the national and Gauteng provincial parliaments.

A second set of 50 girls from Gauteng visited the Sutherland site on 5 August. This group was led by the Gauteng MEC of education, the Honourable Matome Chiloane. They received presentations on astronomy research in South Africa, astronomy for mental health, and opportunities and bursaries for astronomy. They were also given a tour of the Cape Town site.

These two visits demonstrated how key government and parliamentary officials appreciate astronomy, SALT and other telescopes in Sutherland and the benefits of preserving dark skies.

Building on the successful girl-based intervention programme implemented in May, a women's day event was held on 2 September at the SAAO auditorium. A total of 70 girls, drawn from various schools, participated in the programme. They were addressed, motivated and inspired by female scientists and engineers drawn from various fields and disciplines of science, engineering, software development, information technology, food technology and space science. Space and time was created for learners to intimately interact with the various presenters individually and in small groups. This programme was aimed at celebrating women in science, career information dissemination and also to conscientise girls about gender based challenges and constraints.

Public engagement and awareness

The SCBP team presented on astronomy and space based careers at the career exhibition organised by the Seventh Day Adventist Church in Langa on 26 February. The programme was attended by 35 people and included presentations, an exhibition and dissemination of career brochures.

SCBP Sutherland, represented by Jermy Stuurman, participated in the annual Touws River Astronomy week in August. They facilitated a public astronomy workshop which involved 51 members of the public. They also implemented a presentation and hands-on workshop for 81 Grade-6 learners.

The SCBP unit continues to encourage the establishment of science clubs across this country. Science Clubs are vital in conservation and further development of interest in science inspired by a visit to an institution such as ours. The science club from ArcelorMittal Science Centre on the west coast visited SAAO on 18 November to enrich themselves with astronomy knowledge. They were inspired by various astronomy activities including a presentation about the solar system, telescope building and a site tour. There were 60 learners in attendance.

Festivals

SCBP participated in three festivals, namely the Kirkwood Festival (30 June – 2 July), Techno X (14 – 18 August), and the Namaqua Flower Festival (2 – 5 September). At the Kirkwood Festival, 2500 members of the public were reached. Cedric Jacobs presented planetarium shows, an exhibition and hands-on workshops. SAAO science engagement astronomer Daniel Cunnama presented sessions based on his life and work in astronomy for learner participants at the Techno X festival held in Sasolburg in Free State. The Techno X science festival is sponsored by the South African chemicals and energy company Sasol and attracts over a hundred thousand learners and members of the general public annually. At the Namaqua Flower Festival in Springbok in the Northern Cape, Hannes Breytenbach, an SAAO based PhD student, conducted stargazing sessions, with 37 members of the public participating.

National Science Week

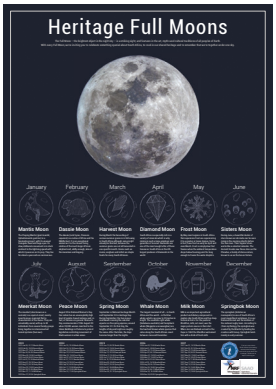
The SCBP team joined the celebrations of the National Science Week (30 July – 4 August) by facilitating programmes in the KwaZulu Natal, Northern Cape and Western Cape provinces. The Northern Cape activities were implemented jointly with the Sutherland Planetarium and included free access to selected planetarium shows for the learners of both Sutherland High and Roggeveld Primary. The interested members of the public were also granted free admission to the shows. A total of 534 learners and 155 members of the public attended the shows. Residents of Sutherland were also offered free tours to SALT and other telescopes on the plateau. The activities in KZN focused on the sun as a star and source of energy, with 441 learners participating in the experiments and hands-on activities. SAAO staff as members of the AfAS participated in various exhibitions, giving career talks and presentations throughout the focus week in the Western Cape.

Open Nights

The Cape Town observatory continues to host Open Night on the second and fourth Saturday of every month. These include a public lecture by an astronomer or PhD student or a technician. The lectures are followed by a site tour and stargazing through small telescopes. In 2023, 24 open nights were held, which included many interesting talks delivered, among others, by SAAO Director Petri Väisänen and SALT software engineer Christian Hettlage. A total of 2612 participants attended the open nights.

Indigenous astronomy

A poster with a set of cultural and heritage full moons was designed and printed, thanks to a collaboration of SAAO and the Centre of Astronomical Heritage. This is a new addition to the three previously developed indigenous/cultural astronomy poster series based on Venus, Canopus and the Pleiades. The artworks are based on Khoi-San, Xhosa and Zulu cultural astronomy and were developed by SCBP. They have been included in the latest version of the open source and freely available planetarium software called “Stellarium”.



The development of tours based on indigenous astronomy in Sutherland has been initiated. This will increase and diversify the number of offerings to our visitors to SALT and other telescopes and will further attract and inspire revisits from past and regular visitors. SAAO outreach staff, with the assistance of indigenous knowledge holders, are hard at work in developing this tour.

Science communication capacity building

A series of meetings with presentations by Sivuyile Manxoyi and Buzani Khumalo from SCBP, Simphiwe Madlanga from SARAO, and Thandile Vuntu from SANSA was held at SAASTA, DSI and SAASTEC for the employees. This culminated in the delivery of an astronomy education and outreach programme for science centre staff as part of the pre-conference workshop for SAASTEC in November 2023 at Scibono, Gauteng. This is part of supporting the development of astronomy programmes, exhibits and shows at science centres in South Africa.

The external newsletter intended to share the relevance and power of astronomy through research and innovative technological developments was established in 2022 and continues to be issued. The third issue, on astronomy related technology, led to a series of interviews, which included SAAO Director Petri Väisänen and Head of Electronics Hitesh Gajjar earning airtime on the 786 Radio Station.

SALT and SAAO impact communication

SAAO's science engagement astronomer, Daniel Cunamma, and SCBP manager, Sivuyile Manxoyi, had an opportunity to address a special government group (consisting of administrators from the departments of tourism, science, security, home affairs and trade) on the significance of the astronomy research infrastructure in Sutherland and how this has benefited the community through astro-tourism.

Sivuyile Manxoyi and Adrian Tiplady from SARAO gave a presentation on the impact of astronomy infrastructure to the Rutgers University post graduate group. Manxoyi highlighted the economic, social, educational, health and cultural benefits that have accrued as a result of the construction of SALT in Sutherland. Manxoyi was also part of the NRF team that presented on the impact of research infrastructure on society at the STFC-initiated conference held in the Czech Republic. He talked on how the construction of SALT has transformed Sutherland from a sleepy rural town into a tourist destination, resulting in the creation of jobs and businesses.

The SCBP team is working on a 25-minute documentary that will highlight the achievements and impact of SALT beyond research, in particular on astro-tourism, which has inspired the development of a national astro-tourism strategy.

Galileo Open Air Cinema outreach

The science engagement team actively participated in the Galileo Open Air Cinema event hosted at Kirstenbosch Gardens in Cape Town on 2 November. The evening's featured film was "Interstellar", which served as a captivating backdrop for our engagement with approximately 350 enthusiastic guests. The SAAO team engaged with the guests, providing valuable insights into the observatory's mission, projects, and contributions to astronomy and science. Their interactions aimed to elucidate SAAO's work and foster a deeper understanding of astronomy's relevance in today's world. They also promoted Sutherland and SAAO Open Nights, and many of the attendees from that evening came to the following Open Night.

Furthermore, Daniel Cunnama delivered a brief but engaging talk that delved into the scientific elements presented in the movie "Interstellar." His discussion provided an illuminating perspective on the science behind the film, connecting it to real scientific concepts, which resonated well with the audience. The SAAO's presence and engagement were met with an overwhelmingly positive response from the attendees. Guests showed great interest and enthusiasm in learning about the observatory's endeavours and the science showcased in "Interstellar". One lucky attendee also won a copy of the popular Karoo Cosmos book. The event not only provided an excellent platform for showcasing SAAO's work, but also facilitated meaningful conversations that highlighted the importance of astronomy and scientific exploration in our society.

Our participation at the Galileo Open Air Cinema was a resounding success, with enthusiastic engagement from a diverse audience. We believe that such outreach efforts significantly contribute to promoting scientific literacy and foster a deeper appreciation for astronomy and related sciences among the public.

Astronomy for mental health

A joint SCBP–IAU OAD intervention programme, based on using astronomy for improving mental health, was implemented at the Community Mental Health and Psychiatry Foundation in Cape Town. This included presentations and selected planetarium shows. Early observations revealed the positive effect of astronomy on the behaviour and attitude of mentally challenged individuals. A total of 63 members of the foundation participated in the programme. This is a continuing programme with a number of interventions being planned.

Presidential Imbizo

SCBP, in collaboration with NRF facilities and DSI institutes, exhibited at the Presidential Imbizo, which was addressed by President Cyril Ramphosa. It was held at Paarl on 19 May, and 107 people visited and interacted with the SAAO and SALT based exhibition.

Tours in Sutherland

A total of 6341 people visited the Sutherland Observatory in 2023. They participated in either the day or the evening tour programme. In the last couple of years, the tours were adversely impacted by the restrictions linked to the COVID-19 pandemic. With the removal of the restrictions, our tours have returned to normal. These tours serve to inform the public of SAAO's infrastructure and research, to inspire the public about the beauty of dark skies and to excite them about the Universe through stargazing. The tours are also a source of income for the facility and contribute to empowerment of the community and the Sutherland town through tourism.

University students visiting SAAO

The Sutherland Observatory remains attractive to both science and art students from various universities. A total of 28 undergraduate physics students from the University of Venda visited both the Cape Town and Sutherland sites on 20 and 21 September, respectively. The aim of the visit was to learn more astronomy and to explore possibilities of pursuing post graduate studies in astrophysics. They were given presentations on astrophysics and a tour of the Cape Town site, including the mechanical and electronics workshops. The Sutherland visit consisted of tours of SALT and the 1.9-m telescope, ending with a stargazing session at the visitor telescopes.

The UCT astronomy department continues to bring the 2nd and 3rd-year students to Sutherland as part of their studies, to provide exposure to research telescopes and dark skies.

Sutherland activities

As part of our efforts to empower the Sutherland youth, a National Student Financial Aid Scheme (NSFAS) workshop was held at the Sutherland Community Development Centre and attracted 18 Grade 11 and 12 learners and their parents. The workshop was aimed at informing attendees about the funding available for technical studies at TVET as well as exposure to all opportunities available for studies at Universities of Technology and other universities.

A science education and community support programme was initiated by the director of the OAD, Kevin Govender, and supported by SCBP staff. This involved parents and 16 learners of the French International school in Cape Town visiting Sutherland on 3 February, where the group was offered tours of various telescopes, along with stargazing. This culminated in a sports programme, exchange of gifts among learners of Sutherland and Cape Town and support for the general community and sport teams.

New Sutherland Manager

A new Sutherland SCBP Manager, Ms Anthea Oliphant, started on 1 August. She brings 16 years of experience in the public sector to the table, specifically in the environment and tourism industry, following her previous position as a Risk and Performance Specialist. She is a born and bred Capetonian who often visited family in the rural areas, which made accepting a position in Sutherland an easy choice. The previous manager, Anthony Mietas, resigned in December 2021 and currently serves as the Mayor of the Karoo Hoogland District municipality.

The Sutherland Community Development Centre and social interventions

Thanks to support from DSI, we received funding to replace all the computers (including the server) and to generally improve the centre. With the new computers, SCBP will be able to provide new forms of training in digital applications and platforms.

A youth-led cultural event was organised by the youth and outreach staff based at Sutherland on 31 March. The event provided an opportunity for the youth of Sutherland to highlight their talents in arts, drama, music and dance. The highlight of the evening was the riel dance and the performance of a play based on constellations. A total of 120 people attended the event.

As part of an on-going Sutherland community support, poverty alleviation and upliftment programme, the Sutherland Community Drive was implemented on 6 May and 21 September. Donations of clothing, bags and toys were distributed to 125 and 112 members of the Sutherland community for those two occasions.

Thanks to SAAO and SALT staff and the Sutherland Donation Drive led by its coordinator, Natalie Jones, we were able to intervene and assist the independent Sutherland based creche after it had experienced arson. Staff donated clothing, toys, appliances, blankets, and learning and teaching materials to support and restore the services and programmes of the creche.

Word of Gratitude and acknowledgement

2023 has been an awesome year for science engagement and socio-economic development. We are grateful to the SALT Board, the SAAO Director and SAAO management for all the support given to SCBP. Sivuyile Manxoyi is grateful to all SCBP staff in Cape Town and Sutherland for their commitment to all our science education, science communication, science awareness and socio economic development programmes.

SCBP highlight: Teacher training

Natural Science is one of the subjects in the South African curriculum for Grades 4 – 9. It is divided into four strands per grade: In the first quarter "Life and Living" is taught, which is mainly biology, then "Matter and Material", which is mainly chemistry, third is "Energy and Change", which is physics, and the fourth is "Earth and Beyond", which is basic astronomy and space science. While training teachers in the Natural sciences is undertaken by most South African outreach programmes, "Earth and Beyond" is the most popular strand and is frequently requested by schools as most teachers were not trained in astronomy during their college studies.

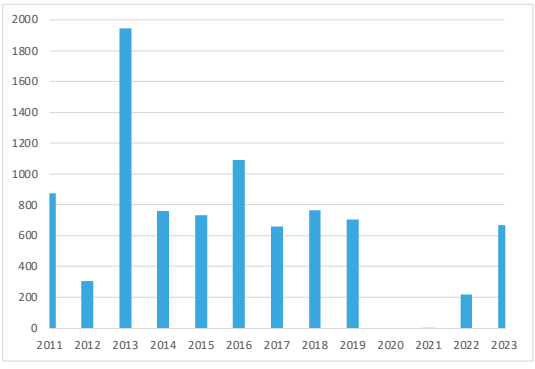
Training and supporting teachers has a positive, and fair to say snowball, effect on the science education system. By empowering and inspiring some teachers, we believe that ultimately their colleagues and learners will also benefit. The improvement of teacher quality and classroom practices in mathematics and science education is thus one of the major commitments of the SCBP. When the "Earth & Beyond" theme was introduced at South African schools, Educational Officer Buzani Khumalo and SCBP programme director Sivuyile Manxoyi started workshops to train teachers in astronomy. The SCBP teacher training programme includes providing relevant curriculum content, exposing teachers to innovative pedagogical approaches and the sharing of modern and creative resources for their classrooms.

SCBP Workshops

Most schools in all the provinces usually request training on "Earth and Beyond". Schools to receive the training are selected by curriculum advisers for Natural Science from the education district offices in the provinces according to districts and the grades they want us to focus on. They book the dates and we fit them into our year plan calendar. Unfortunately, we can only accommodate three or four training sessions per year. There are also times where we initiate the training session on our own so as to cover the rural areas, but the education district offices still have the responsibility to choose schools in the districts that need more support.

The training involves the topics in the curriculum that cover basic astronomy such as the solar system, phases of the moon, galaxies, telescopes, Earth's revolution and rotation, birth, life, and death of stars (stellar evolution), tides, indigenous astronomy, rockets, rovers etc. We started online training during COVID-19 lockdowns, but most training is still face-to-face due to network challenges that schools face, especially in rural areas.

The training is usually done in the form of powerpoint presentations and hands-on activities relevant for the particular grade we focus on during the workshop. We also supply the presentation via USB, as per teachers' preference. While the textbooks used are selected by the department of education, we refer to the information in the text books and adapt and supplement the information according to the current knowledge in astronomy, in particular in the case of misconceptions, or where textbook information is outdated. While the lesson plans are set by curriculum subject advisers as per the CAPS system, we sometimes suggest different methods for teaching "Earth and Beyond" for clarity purposes.



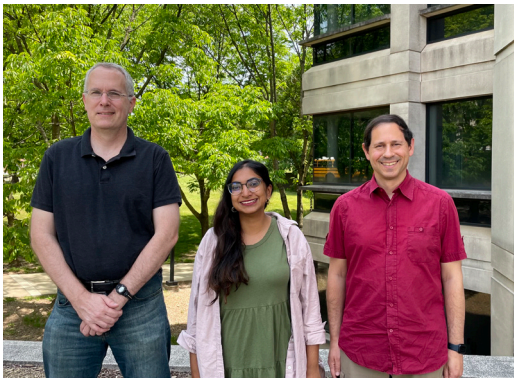
The number of educators trained since 2011. The effect of the COVID-19 restrictions resulted in an obvious gap.

While we offer various hands-on activities, most teachers request telescope building as the main activity, because the telescope is part of the curriculum. Our presentation includes explanations about different types of lenses, and how lenses and mirrors work in telescopes. Afterwards, they execute the activity themselves to gain experiences.

Photos top to bottom:
Buzani Khumalo giving her presentation.
Preparing materials.
Making use of kitchen materials.

OUTREACH AND EDUCATION:
SALT partner outreach programmes

SALT-Stobie research visit at Rutgers University



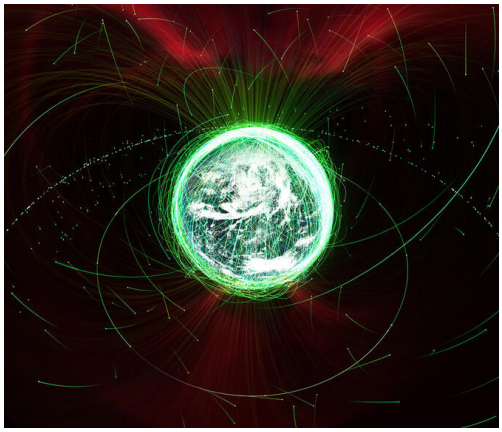
From left to right: Andrew Baker, Munira Hoosain and Eric Gawiser at Rutgers University.

Munira Hoosain is a PhD student at UCT/SAAO and supervised by Sarah Blyth (UCT) and Ros Skelton (SAAO, SALT). She studies neutral hydrogen gas in galaxies as part of the MeerKAT survey LADUMA. She was awarded funding for a research visit to Rutgers University in New Jersey (USA) in March 2023. During her stay, she worked with Andrew Baker and Eric Gawiser on her research, reducing SALT data for galaxies in the LADUMA survey. The visit allowed Munira to collaborate closely and in person with both of her hosts as well as their research groups. After three years of pandemic restrictions, this opportunity was essential for strengthening the existing networks between South Africa and Rutgers, as well as to develop new ones. During the two-month visit, Munira participated in the research activities of the Physics & Astronomy Department at Rutgers, such as journal club meetings and seminars. She also gave a presentation at the departmental Equity & Inclusivity Journal Club on the history and current state of astronomy in South Africa. Overall, the research visit was a positive and scientifically enriching experience for Munira.

American Museum of Natural History

As part of its outreach efforts, the American Museum of Natural History has transferred its sixth spaceshow “Worlds Beyond Earth” to the Naval Hill Planetarium in Bloemfontein for its South African premier. The show was shown to the SALT Board of Directors during its meeting in Bloemfontein in November 2023.

Narrated by the Mexican-Kenyan actress Lupita Nyong’o, ”Worlds Beyond Earth” tells the story of the worlds in our solar system, groundbreaking space missions and the conditions that make life on Earth possible. The presented scenes are based on real data and include immersive visualisations of the alien landscapes of Mars and Titan as well as simulations of the evolution of Saturn’s rings and the creation of the solar system.



Earth’s technosphere, showing an array of human-made satellites in their orbits. – Credit: AMNH.

Dartmouth College

From January to March 2023, SALT partner Dartmouth College continued its fruitful partnership with the South African astronomical community, holding its fourth biennial Astronomy Foreign Study Program in Cape Town and Sutherland. Eighteen Dartmouth undergraduates hailing from around the world spent their winter term in South Africa, carrying out coursework at the University of Cape Town, with each student also spending a week observing at the SAAO facilities in Sutherland and visiting SALT.

In addition to the academic work and research on RR Lyrae stars and cataclysmic variables, the students had many opportunities to engage with South African culture and society. Highlights included trips to Robben Island and the District Six museum, a trip up Table Mountain, and cheering South Africa’s epic Women’s Cricket World Cup victory over England at Newlands.

The programme was led by the SALT Board director Brian Chaboyer, along with Dartmouth Professors Ryan Hickox and John Thorstensen. The programme would not have been possible without contributions from Narges Hatamkhani from SAAO, who contributed to lectures, our colleagues at CIEE, who organised housing and other key aspects of the programme, the helpful and welcoming staff at the UCT Department of Physics, and of course our amazing colleagues at SAAO and SALT!

VISITING SALT

Delegations and official visits

In 2023, the following parties visited SALT.

14 – 15 February: Ambassadors of Ireland and Finland
Ambassador of Finland, Ms. Anne Lammila
Ambassador of Ireland, Ms. Fionnuala Gilsenan
Prof. Petri Väisänen, Director of SAAO

Petri Väisänen showed the Sutherland facilities, including SALT, as well as the spectacular night-sky to the Ambassadors of Ireland and Finland. They were very impressed by what they saw. The visit included a fabulous dinner and breakfast at the hostel. The ambassadors even gate-crashed the SALT morning meeting to get coffee during their brisk morning walk up and down the hill.

17 – 19 October: SALT External Review Panel
Prof. G.C. Anupama (IIA Bangalore, India)
Prof. Nithaya Chetty (University of Witwatersrand, South Africa)
Prof. Patrick Roche (Oxford University, UK)
Prof. Brian van Soelen (University of Free State, South Africa)

The SALT external review panel visited SALT during their week-long deliberation on SALT matters.

On the way to Sutherland, the external reviewers enjoy the colourful display of South African's wildflowers.

18 - 19 October: BRICS Astronomy Working Group

Members of the 9th Annual BRICS Astronomy Working Group, whose meeting was held at SAAO, visited the MeerKAT and SALT sites on 18 October. They received a full tour of the site, including the MeerLICHT and Lesedi telescopes.

November: SALT Board meeting attendees
Prof. Raghunathan Srianand (IUCAA, India)
Prof. Brian Chaboyer (Dartmouth College, USA)
Dr Itumeleng Monageng (SAAO, South Africa)
Prof. Gordon Bromage (University of Central Lancashire, UK)

This year's November SALT Board meeting took place at Boyden Observatory in Bloemfontein. The participants also visited the Naval Hill Planetarium (previously the Lamont-Hussey Observatory), and afterwards, four of the attendees came to the Sutherland site. During the visit, the board members got to see the telescope in action and were provided with a tour of the updated instruments and software. They engaged in discussions with the telescope's staff, learning about new capabilities and challenges. Overall, it was an experience that provided good, firsthand knowledge and strengthened the board's connection to SALT's missions and objectives.

Media visits to SALT

February 2023 — Mal Kamper TV

Dewald Visser is Managing Director at Rat Race Media and presenter of the outdoor show Mal Kamper on South Africa's kykNET. The show depicts the scenic beauty of Africa and all its outdoor splendour, explored by Visser using various outdoor activities. On 11 February, he visited SALT by bike and filmed the Sutherland tour. The show was broadcast in March, the video can be found here: https://vimeo.com/813460257.

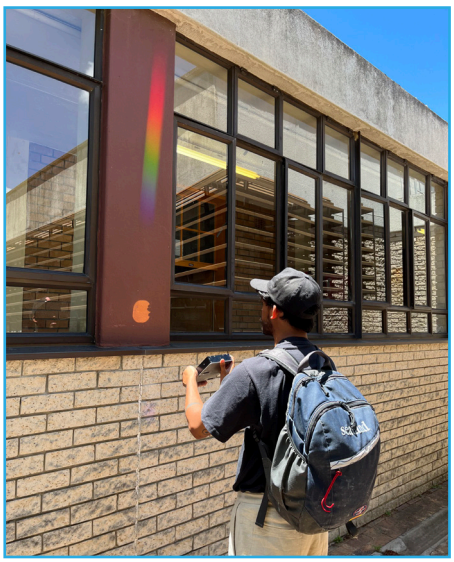
February 2023 — Trouw newspaper

Kevin van Vliet is a Foreign Correspondent for the Dutch newspaper Trouw (meaning 'true' or 'loyal' in English). He visited Sutherland on 21 February 2023 for the purpose of writing an article about SALT. SALT electronic engineer Willem van der Westhuizen showed him around. Kevin brought a photographer with him, who mostly took photos of tour groups visiting SALT. Etienne Simon, an electronics technician at SALT, did the presentations. The article was published on 31 May 2023.

September 2023 — Valkhof museum

From 9 – 12 September South African artist Kamil Hassim filmed at Sutherland observatory, shadowing SALT Observatory Scientist Lisa Crause.

Kamil Hassim is a trans-disciplinary artist and musician, known for his innovative work that blends art, science, and indigenous knowledge systems. Hassim is fascinated by the interconnectedness of space and time and how they shape our reality, which he explores through his art. In 2023, Hassim was artist in residence at SAAO, collaborating on a project that combines fundamental physics (he also spent some time at CERN, in Switzerland), modern African astronomy, and ancient indigenous cosmologies.



One of his notable works is “Event Horizon”, an immersive optical installation. This exhibition plays with constructed and deconstructed information, perception, and optical effects using defunct diffraction gratings used in astronomy. The work creates a sensory experience, exploring concepts related to black holes and the mysteries of the universe, using light projected in an old apartheid prison cell. The exhibition is a collaboration with SAAO and was shown in Johannesburg in March 2023, and in Cape Town in June. From October until April 2024 it will be displayed as part of the international group exhibition “Into the Black Hole” at the Valkhof museum in Nijmegen in the Netherlands. The museum requested a short video of 3 – 5 minutes to be exhibited alongside the installation. The film explores the themes and concepts behind Kamil’s installation and its relationship to his time at SAAO. The film will play alongside the exhibition and online.

September 2023 — VentureKJ Photography

VentureKJ is a collaboration between the two well-known South African nature photographers, Jon Kerrin and Kyle Goetsch. They offer guided photography workshops, specialising in travelling to remote locations of scenic beauty. On 12 September, Jon Kerrin took a group of like-minded people to Sutherland to take night-time images of the Observatory.

SALT exhibitions at science meetings

10 July – 14 July: EAS Annual Meeting, Kraków, Poland

SALT made a significant contribution to the European Astronomical Society’s Annual Meeting in Kraków, Poland, underscoring the importance of Africa-Europe collaborations in the field of astronomy. The delegation’s participation was a testament to SALT’s commitment to fostering international partnerships and highlighting the role of African astronomy on the global stage.

A highlight of the conference was a Special Session dedicated to Africa-Europe collaboration, which focused on the anticipated impact of the 2024 IAU General Assembly on the development of astronomy. This session served as a platform for discussing future projects and initiatives, aiming to strengthen ties between the two continents and explore new opportunities for cooperation in astronomical research and education. The session included a talk by SAAO’s Science Engagement Astronomer, Daniel Cunnama, on “Advancing Science Engagement: The Impact of the South African Astronomical Observatory and SALT”, providing insight into the SAAO’s efforts to enhance science communication and public engagement. Through initiatives involving SALT, SAAO has played a pivotal role in advancing astronomical research and fostering a deeper appreciation of the universe among the general public.

SALT’s involvement in the EAS Meeting not only highlighted its achievements and ongoing projects but also invited the international astronomical community to Africa for the upcoming IAU General Assembly. This invitation reflects the growing significance of African astronomy and the continent’s potential to contribute to our understanding of the universe. Overall, SALT’s participation in the EAS Meeting emphasised the importance of international collaboration in astronomy, the impact of public engagement in science, and the role of Africa as a rising star in the astronomical community.

CORPORATE GOVERNANCE

The affairs of the SALT Foundation are regulated by the Shareholders' Agreement, signed at the formation of the Company. In terms of this agreement, the Company is controlled by a Board of Directors comprising two members from the National Research Foundation, one member from each of the remaining partner institutions and two additional members. The Directors are elected at the Annual General Meeting of the Company and serve for a period of three years, following which they may be re-elected. All Board members are independent, Non-Executive Directors.

In this reporting period, the Board comprised of the following members:

Prof. Brian Chaboyer (Chair)
Dartmouth College, USA

Prof. Matthew Bershady
University of Wisconsin–Madison, USA

Prof. Phil Charles
United Kingdom SALT Consortium, UK

Dr. Sharmila Goedhart
South African Radio Astronomy Observatory, South Africa

Prof. Krzysztof Hełminiak
(Appointed Oct 2023)
Nicolaus Copernicus Astronomical Centre, Poland

Prof. John P. Hughes
Rutgers University, USA

Dr. Vanessa McBride
National Research Foundation, South Africa

Dr. Itumeleng Monageng
University of Cape Town, South Africa

Dr Fulufhelo Nelwamondo
National Research Foundation, South Africa

Prof. Somak Raychaudhury
(Resigned Jan 2023)
Inter–University Centre for Astronomy & Astrophysics, India

Prof. Marek Sarna
(Resigned Sept 2023)
Nicolaus Copernicus Astronomical Centre, Poland

Prof. Michael Shara
American Museum of Natural History, USA

Prof. Raghunathan Srianand
(Appointed Jan 2023)
Inter–University Centre for Astronomy & Astrophysics, India

Other officers of the Company include Mrs Lizette Labuschagne (Chief Financial Officer, Company Secretary and Business Manager).

The Board meets twice a year, usually in May and November. The SAAO Director and senior staff involved in the operation of the telescope also attend the Board meetings.

Operations contract

SALT is operated on behalf of the SALT Foundation by SAAO and managed by the SAAO Director, Prof. Petri Väisänen. The majority of the staff who carry out the day-to-day operational activities are SAAO employees. Engineering operations are managed by the SALT Technical Operations Manager, Mr Paul Rabe, while Dr Encarni Romero Colmenero heads the Astronomy Operations team. The operations plan and budget are presented by the SAAO Director at the November Board meeting for the following financial year.

The Board Executive Committee (BEC)

The Board has delegated authority to the Board Executive Committee (BEC) to manage the Company during the period between Board meetings. The BEC meets once or twice between Board meetings and receives reports on the operations and development of the telescope from the SAAO Director and other senior staff with the relevant responsibilities. The BEC comprises six Board members. In this reporting period, they were: Prof. Brian Chaboyer (Chair), Prof. Phil Charles, Prof. Jack Hughes, Prof. Raghunathan Srianand, Dr Fulufhelo Nelwamondo and Prof. Mike Shara.

The Finance and Audit Committee (FAC)

Although the full Board takes responsibility for the Annual Financial Statements of the Company, the Board has appointed a Finance and Audit Committee (FAC) to interrogate the management of the financial affairs of the Company at a detailed level. This committee meets at least twice a year, shortly before Board meetings, and presents a report at the Board meeting. In this reporting period, the members of the FAC were: Prof. Jack Hughes (Chair), Prof. Gordon Bromage, Dr Matt Bershady, Mrs Kate Soule and Prof. Brian Chaboyer (ex officio).

Scientific and Technical Committee (STC)

The Scientific and Technical Committee (STC) was established in November 2018, as per recommendations arising from the SALT External Review. The fundamental purpose of this committee is to improve all levels of technical and scientific communication within the SALT collaboration, with the explicit goal of increasing the scientific productivity of the telescope. The SALT Observatory Scientist is a member of the committee. The STC reports to the SALT Board via the chair of the committee. In this reporting period, the members are: Dr Lisa Crause (Chair), Prof. Paul Groot, Prof. Matt Bershady, Mr John Booth, Prof. Joanna Mikołajewska, Dr David Buckley and Prof. Raghunathan Srianand.

** part-time and/or part of the year*

Technical Operations Team 2023

Paul Rabe (Head)

Shamiel Adams
Richard Banda
Janus Brink
Bryne Chipembe
Alrin Christians*
Willa de Water
Timothy Fransman
Denville Gibbons
Johan Hendricks
Nicolaas Jacobs
Anita Jonker*
Sunnyboy Kabini
Anthony Koeslag
Deon Lategan
Jonathan Love*
Thabelo Makananise
Tasheen Naicker
Jonathan Pieterse
Melanie Saayman
Etienne Simon
Nicolaas van der Merwe
Willem van der Westhuizen
Eben Wild

Astronomy Operations Team 2023

Encarni Romero Colmenero (Head)

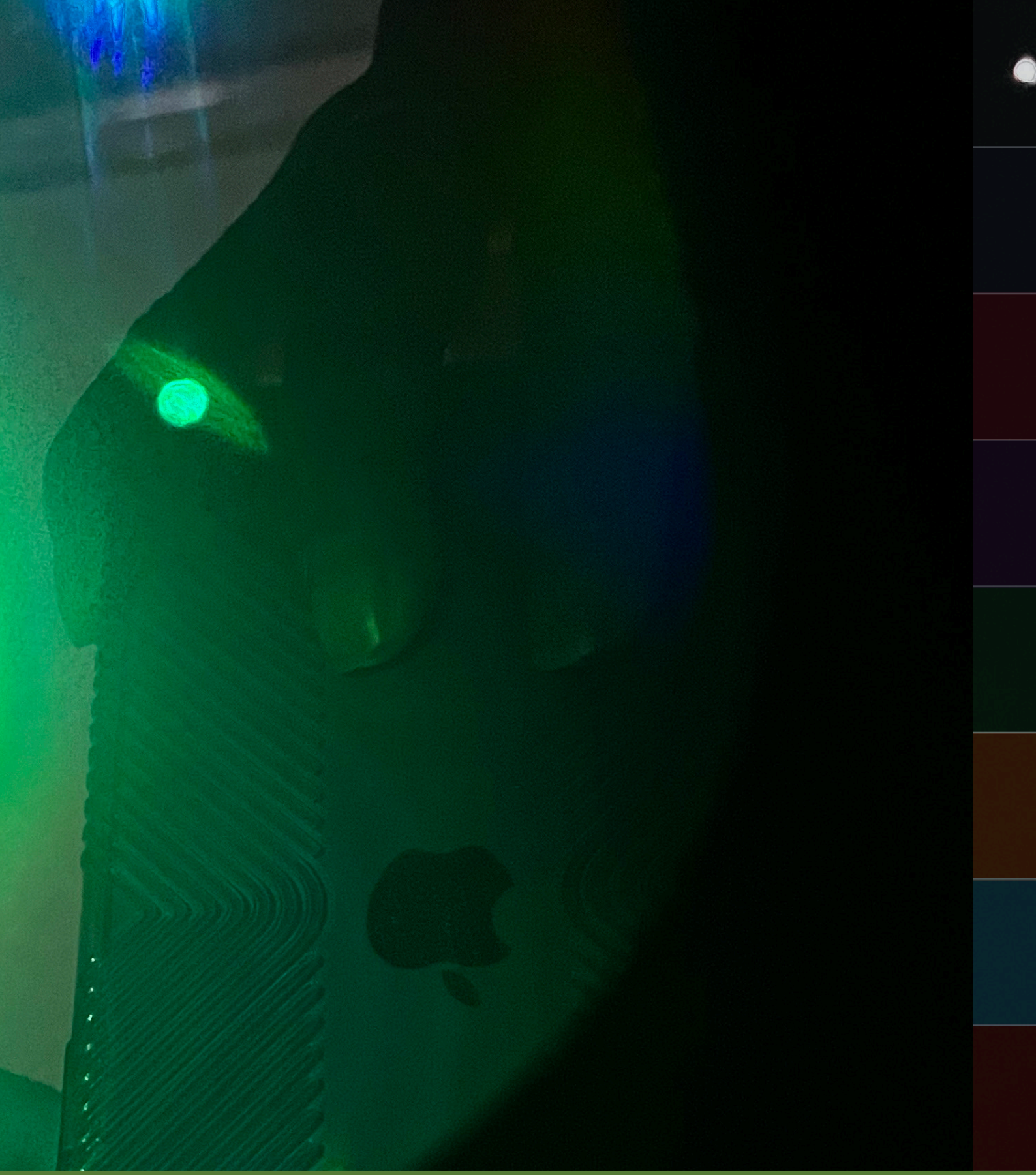
Danièl Groenewald
Christian Hettlage
Alexei Kniazev
Thea Koen
Enrico Kotze
Rudi Kuhn
Nhlavutelo Macebele
Chaka Mofokeng
Moses Mogotsi
Xola Ndaliso
Solohery Randriamampandry
Anja Schröder*
Rosalind Skelton
Lee Townsend
Veronica van Wyk

SALT Observatory Scientist 2023

Lisa Crause

Corporate Governance Team 2023

Lizette Labuschagne
Surayda Moosa



LIST OF PUBLICATIONS

Refereed publications*

Aharonian, F., et al. 08/2023: “The Vanishing of the Primary Emission Region in PKS 1510-089”, ApJL, 952, L38

Aromal, P., et al. 07/2023: “Time variability of ultra fast BAL outflows using SALT: C IV equivalent width analysis”, MNRAS, 522, 6374

Aydi, E., et al. 09/2023: “Catching a nova X-ray/UV flash in the visible? Early spectroscopy of the very slow Nova Velorum 2022 (Gaia22alz)”, MNRAS, 524, 1946

Bostroem, K. A., et al. 08/2023: “SN 2022acko: The First Early Far-ultraviolet Spectra of a Type IIP Supernova”, ApJL, 953, L18

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GLOSSARY & ACRONYMS

1D, 2D, 3D	one, two, three dimensional
ACT	Atacama Cosmology Telescope
ACT-CL	ACT cluster (object name prefix)
AdvACT	Advanced ACT
AfAS	African Astronomical Society
AGB	asymptotic giant branch
AGN	active galactic nucleus
AIP	Leibniz Institute for Astrophysics Potsdam
ALMA	Atacama Large Millimeter/submillimeter Array
AMNH	American Museum of Natural History
AMU	Adam Mickiewicz University
AOP	Armagh Observatory & Planetarium
AR	anti-reflective
ASASSN	All Sky Automated Survey for SuperNovae
ASSET	Association in Educational Transformation
ATL	ATLAS (catalogue ID)
ATLAS	Asteroid Terrestrial-impact Last Alert System
ATO	ATLAS object (catalogue ID)
ATOM	Automatic Telescope for Optical Monitoring
BCAM	backup camera for SALT
BEARS	Bright Extragalactic ALMA Redshift Survey
BEC	board executive committee
BLR	broad line region
BPS CS	Beers, Preston, Shectman (catalogue ID, using the Curtis Schmidt telescope)
BRICS	Brazil, Russia, India, China, and South Africa
BRITE	BRIght-star Target Explorer
BSDL	Bica, Schmitt, Dutra, L.Oliveira (catalogue ID)
CalSys	calibration system
CAMK	Nicolaus Copernicus Astronomical Center
CAPS	Curriculum and Assessment Policy Statement
CCD	charge-coupled device
CERN	Conseil Européen pour la Recherche Nucléaire
CHIETA	Chemical Industry Education and Training Authority
CHT	compact hierarchical triples
CIEE	Council on International Educational Exchange
CMOS	complementary metal-oxide semiconductor
CNO	carbon, nitrogen, oxygen
Co–PI	co–principal investigator
COVID-19	coronavirus disease 2019
CTA	Cherenkov Telescope Array
CV	cataclysmic variable star
DC	Dartmouth College
DDT	director's discretionary time
DIMM	differential image motion monitor
DSI	Department of Science and Innovation
EAS	European Astronomical Society
EB	eclipsing binary
EC	Edinburgh-Cape survey
EDV	eclipse depth varying
ELS	event logging system
EOM	electro-optic modulator
eROSITA	extended ROentgen Survey with an Imaging Telescope Array
ESA	European Space Agency
ESO	European Southern Observatories
FAC	finance and audit committee
Fermi-LAT	Fermi Large Area Telescope collaboration
FIR	far-infrared
FIF	fibre instrument feed
FITS	flexible image transport system
FP	Fabry–Pérot
FRD	focal-ratio degradation
FWHM	full width half maximum
GALEX	Galaxy Evolution Explorer (UV space telescope)
GATS	Global Astrophysical Telescope System
GRB	gamma-ray burst
GPP	Guider Pre-Positioner
GTC	Gran Telescopio Canarias
GU	Göttingen University
H2RG	HAWAII–2RG detector
HD	Henry Draper
HE	Hamburg–ESO survey
H.E.S.S.	High Energy Stereoscopic System
HET	Hobby–Eberly Telescope
HETDEX	HET Dark Energy eXperiment
HIPASS	H I Parkes all-sky survey
HMXB	high-mass X-ray binary
HR	Harvard obs., revised photometry (catalogue ID)
HRS	high-resolution spectrograph
HS	high-stability
HST	Hubble Space Telescope
HWU	Heriot-Watt University
IAO	Institute Astronomical Observatory
IAU	International Astronomical Union
IEEE	Institute of Electrical and Electronics Engineers
IFU	integral field unit
IIA	Indian Institute of Astrophysics
INASAN	Institute of Astronomy of the Russian Academy of Sciences
IRAF	Image Reduction and Analysis Facility
IRAS	Infrared Astronomical Satellite
ISDEC	IUCAA SIDECAR Drive Electronics Controller
ISI	international scientific indexing
ISM	interstellar medium
IUCAA	Inter–University Centre for Astronomy & Astrophysics
JSON	JavaScript Object Notation
JWST	James Webb Space Telescope
KAT	Karoo Array Telescope
KZN	University of KwaZulu-Natal
LADUMA	Looking At the Distant Universe with the MeerKAT Array
LBT	Large Binocular Telescope
LED	light-emitting diode
LFC	laser frequency comb
LIGO	Laser Interferometer Gravitational wave Observatory
LMC	Large Magellanic Cloud
LMXB	low-mass X-ray binary
LOFAR	LOw Frequency ARray
LSP	SALT large science programme
LSSTC	Large Synoptic Survey Telescope Corporation
MASCARA	Multi-site All-Sky CAmeRA
MASS	multi-aperture scintillation sensor

MASTER	Mobile Astronomical System of the TElescope–Robots network
MaxE	Maximum Efficiency spectrograph
MAXI	Monitor of All-sky X-ray Image
MEC	Ministry of Education
MCSNR	Magellanic cloud SNR (catalogue ID)
MDM	Michigan–Dartmouth–MIT Observatory
MLT	SALT multi-semester proposal
MOS	multi-object spectrograph
MPE	Max-Planck-Institut für extraterrestrische Physik
MS	main sequence
MSc	master of science
NCAC	Nicolaus Copernicus Astronomical Center
NCON	NIR instrument control
NGC	New General Catalog
NIR	near-infrared
NIRWALS	NIR Washburn Astronomical Labs Spectrograph
NRC	National Research Council (Canada)
NRF	National Research Foundation (South Africa)
NS	neutron star
NSF	National Science Foundation (USA)
NSFAS	National Student Financial Aid Scheme
NuSTAR	Nuclear Spectroscopic Telescope ARray
NUV	near-UV
NWU	North–West University
OAD	Office of Astronomy for Development
OAE	Office for Astronomy Education
OGLE	Optical Gravitational Lensing Experiment
OPC UA	open platform communications united architecture
OPTICON	Optical Infrared Coordination Network for Astronomy
ORP	OPTICON/Radio-Net project
P0 … P4	priority 0 – 4
PAN	Polska Akademia Nauk (=PAS)
PAS	Polish Academy of Sciences
PDET	PFIS (now RSS) detector
PDR	preliminary design review
PFIS	Prime Focus Imaging Spectrograph (now RSS)
PG	Palomar obs., Green (catalogue ID)
PhD	doctor philosophiae
PI	principal investigator
PIPT	Principal Investigator Proposal Tool
PKS	Parkes radio telescope (catalogue ID)
PLATO	PLAnetary Transits and Oscillations of stars (ESA mission)
PLC	programmable logic controller
PLM	product lifecycle management
PN	planetary nebula
POL	Poland
PPC	Parliamentary Portfolio Committee
RINGS	RSS Imaging spectroscopy Nearby Galaxies Survey
RN	recurrent nova
RS	reversed shock
RSA	Republic of South Africa
RSS	Robert Stobie Spectrograph
RU	Rutgers University
SA	South Africa
SAAO	South African Astronomical Observatory
SAASTA	South African Agency for Science and Technology Advancement
SAASTEC	South African Association of Science and Technology Centres
SAI	Sternberg Astronomical Institute
SALT	Southern African Large Telescope
SALTICAM	SALT Imaging CAMera
SAMMI	SALT Astronomer Man Machine Interface
SANBI	South African National Biodiversity Institute
SANSA	South African National Space Agency
SARAO	South African Radio Astronomy Observatory
SCBP	SALT Collateral Benefits Programme
SCI	SALT science proposal
S–CUBED	Swift SMC Survey
sd	subdwarf
SDC	structure and dome control
SDSS	Sloan digital sky survey
SED	spectral energy distribution
SIDECAR	system image, digitising, enhancing, controlling, and retrieving
SKA	Square Kilometre Array
SMBH	supermassive black hole
SMC	Small Magellanic Cloud
SMI	slit mask IFU
SN	supernova
SNR	supernova remnant
SSS	super soft X-ray source
STC	scientific and technical committee
STEM	science/technology/engineering/ mathematics
SUNBIRD	SUperNovae and starBursts in the InfraReD
SuperWASP	Super Wide Angle Search for Planets
TAC	time allocation committee
TCS	telescope control system
TESS	Transiting Exoplanet Survey Satellite
TIC	TESS input catalogue object
TMT	Thirty Meter Telescope
TVET	Technical and Vocational Education and Training
U	university
UCLan	University of Central Lancashire
UCN	University of Canterbury
UCT	University of Cape Town
UFS	University of Free State
UI	user interface
UKSC	United Kingdom SALT Consortium
ULIRG	ultra-luminous infrared galaxy
UNC	University of North Carolina – Chapel Hill
UNESCO	United Nations educational, scientific and cultural organisation
UV	ultraviolet
UVOT	Swift's UltraViolet and Optical Telescope
UW	University of Wisconsin–Madison
UWC	University of the Western Cape
VHE	very high energy
VIS	visible
VLBI	very long baseline interferometry
WM	web manager
XML	extensible markup language
XMM	XMM–Newton observatory
XMMU	unique XMM source
XRT	X-ray telescope

The SALT consortium is seeking an additional 10%-level partner (~$10.5M) to support significant second-generation instrumentation development. Interested parties should contact the chair of the SALT Board of Directors, Brian Chaboyer*.

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