SOUTHERN AFRICAN LARGE TELESCOPE

ANNUAL REPORT 2020

Remote observing at SALT

The spread of the COVID-19 pandemic, with its various restrictions on people's movements and gatherings, had a severe effect on astronomical observatories world-wide. SALT was able to react very quickly and was one of the first 10-m class telescopes to take up observing again: after 5 weeks of hard lockdown it took only one more week of adjustments, and SALT was ready for remote observing.

COVID-19 time line in South Africa

There are five lockdown levels in South Africa, ranging from the most severe Level 5 (drastic measures are required: all people stay home, except for shopping, essential work, and emergencies) to Level 1 (most normal activity can resume, with precautions and health guidelines followed).

5 March: first COVID-19 case confirmed
18 March: confirmation of 100th case

Starting dates of lockdown levels

27 March	5
1 May	4
1 Jun	3
18 Aug	2
21 Sep	1
29 Dec	3

Shutdown periods of other large telescopes

HET:	0 days (established early remote obs)	
GTC:	30 Mar - 22 Apr:	24 days
SALT:	27 Mar - 7 May:	42 days
Keck-2:	24 Mar - 13 May:	50 days
Subaru:	25 Mar - 18 May:	54 days
Keck-1:	24 Mar - 20 May:	57 days
Gemini-N:	23 Mar - 19 May:	57 days
ESO/VLT:	25 Mar - 13 Sep:	5.5 months
Gemini-S:	16 Mar - 20 Oct:	7 months

With South Africa going into Level 5 lock-down on midnight of 26 March 2020, SALT was limited to allowing critical maintenance staff in the facilities only when required and for daily system checks. This meant that no SALT Astronomers (SAs) or Operators (SOs) were able to observe from the Sutherland site during this period.

We already had the system in place to remotely log into any subsystem at SALT via VNC or Remote Desktop (RDP) which meant we could monitor all alarms (e.g., rain) and environmental conditions (e.g., wind, humidity), and control the telescope remotely. Critical alarms such as fire and glycol leaks are also SMS'ed to stand-by staff. However, the telescope could only be operated with someone present at the telescope who could listen for strange noises, which is an indication that something mild to catastrophic is about to happen, or be available to address any other odd facility issues. Therefore, the team decided to do a risk analysis of what was required to ensure the safety of the telescope and people under remote operations. This included telescope movement while someone is at the telescope (already mitigated with standard operating procedures of using a lockout panel); glycol leaks (already mitigated with the installation of leak detectors and system temperature warnings); extra on-site telescope checks, usually done by the SO, to be performed by stand-by staff; very rare events like an odd snake in the control room or a geyser leak, which could now only be sorted out by the day crew. The main risk to be addressed was the telescope sound. Since we already had a sound system in place with microphones throughout the telescope, we only needed to improve the sound quality, such as getting rid of electrical interference, and to hook it up to an audio streaming service on the Operator's HMI (human machine interface). With the risks mitigated, the SO and SA could now log in to their respective HMI's from home, open the audio streaming service, and by using a Zoom session between them, were able to successfully continue with night time operations since 8 May.

The only other issues generally out of our control is the occasional Eskom* load shedding and internet downtime at the remote locations. Mitigating this depends on the circumstances surrounding the individual remote locations. Sometimes an SO or SA would observe from the Cape Town office to minimise these risks: SALT and SAAO had implemented a GSM LTE network as a backup link in case the main internet fibre link to Sutherland went down. However, that was slightly restrictive on bandwidth. A new backup fibre route is being planned in the near future to mitigate this risk.

* South Africa has experienced frequent load shedding (or scheduled brown-outs) in the last couple of years due to ageing equipment and increased needs.

Veronica (SALT Operator)

I must admit I was very scared at first, but also very excited, when I heard that we can do remote observing from home. Surprisingly all system worked well. Had a bit of wireless connection issues together with Eskom* problems. But with the technology today you can plug in a portable UPS and stay connected for the period when the electricity is off. The scary part for me was when I had to close the dome in the mornings. I always have this fear that I didn't close the dome or louvres properly. I always shone my torch onto the telescope at the end of my night.It just freaked my out to know that I couldn't do that anymore. Luckily I found out about the tracker camera in the telescope, which eased some of my paranoia. I guess it will forever be freaky not to be at the telescope, especially when the weather is not nice.

Danièl (SALT Astronomer)

I was the last SALT astronomer to observe on SALT before the lockdown took effect. But even during that week, the 'normal' observing routine was no longer the same. Veronica (SO) decided to operate SALT from her home on site to limit exposure. On the last morning, three tired astronomers piled into the transport at 8 am for the drive to Cape Town. We left earlier than usual to prepare for the upcoming lockdown. I felt sad leaving, knowing it would be a while before I get back to Sutherland. Though enjoying the comfort of my own lounge, remote observing, along with juggling family lives and trying to sleep during the day with noisy neighbours, is challenging. It is unreal observing from Cape Town, where it is pouring with rain, and opening the dome in Sutherland, where the skies are clear. I do miss the solitude Sutherland offers, where you can just concentrate on observing. Challenges aside, we are blessed that we can still deliver observations to the wider science community, while also striving to keep our families and colleagues safe.

Lee (SALT Astronomer)

I've been remote observing from my apartment in Sea Point on Beach Road. The pros are that I can listen to the waves whilst observing :-) Plus the full moon looks amazing shining off the ocean! The cons are that there has been almost constant construction work in my building since the new year. It's very hard to sleep during the day when "core drilling" starts at 9am! Last time I even made a 'sound damping' tent to sleep in with mattresses and blankets as walls! I can't wait to go back to Sutherland!!

Ros (SALT Astronomer)

When SALT was allowed to take up essential services again, there was much discussion about risks, the health implications of working through the night during a pandemic and the practicalities, like how best to connect to the SALT computers and make backup plans for losing power, or internet connections during the night. Alexei wasted no time in trying out all connections, and just a few days after the team meeting SALT was up and running, with Alexei and Veronica observing from their homes.

Thea and I took the second shift, each observing from our lockdown work-from-home spaces and talking to each other throughout the night over Zoom. In the control room, SALT's multiple instrument interfaces and control computers are displayed simultaneously on big screens, but there is much less screen space at home. It took some time to find the best way to view and easily switch between all the SALT windows and get used to the checks needed for remote observing, like making sure the dome lights are off and sounds from the telescope and instruments are still coming through.

Initially I connected to the SALT computers using three different VNC programs, each machine having its personal preference and requiring a slightly different setup. Some instruments gave us more trouble than other and every now and again we'd lose all the connections simultaneously and have to begin the laborious start-up process again. Luckily it didn't take long to optimise the setup and get used to the new way of working. I still miss the starry skies of Sutherland, and coming out into a beautiful Karoo dawn after a night of observing, but the comforts of home and the shortest possible commute to bed after a shift are very much appreciated!

Sound bites from the observing logs

24 Mar

SA: Danièl SO: Veronica

This is SALT's last night of science before we shutdown operations for the next 3 weeks, doing our part in "flattening the curve". I hope everyone stays safe.

7 May

SA: Alexei SO: Veronica

Others: by Zoom session: Encarni, Paul, Alexei, Veronica and tech-obs at the telescope

First night for tests after long break for the reason of lock-down. Very bad weather with cirrus and bright Moon, otherwise everything looks working. Hope to start real observations tomorrow.

8 May

Very productive first night of observations with bright moon, good seeing and stable weather conditions. Only blocks with high priority were observed. Thanks a lot a for working telescope!!! No any technical problems!!!

13 May

SA: Ros SO: Thea

At the end (6 am) Thea and I both lost all our connections, VPN and zoom simultaneously, which seems strange!

15 May

Some delays with the VNC screens taking long to refresh at times tonight.

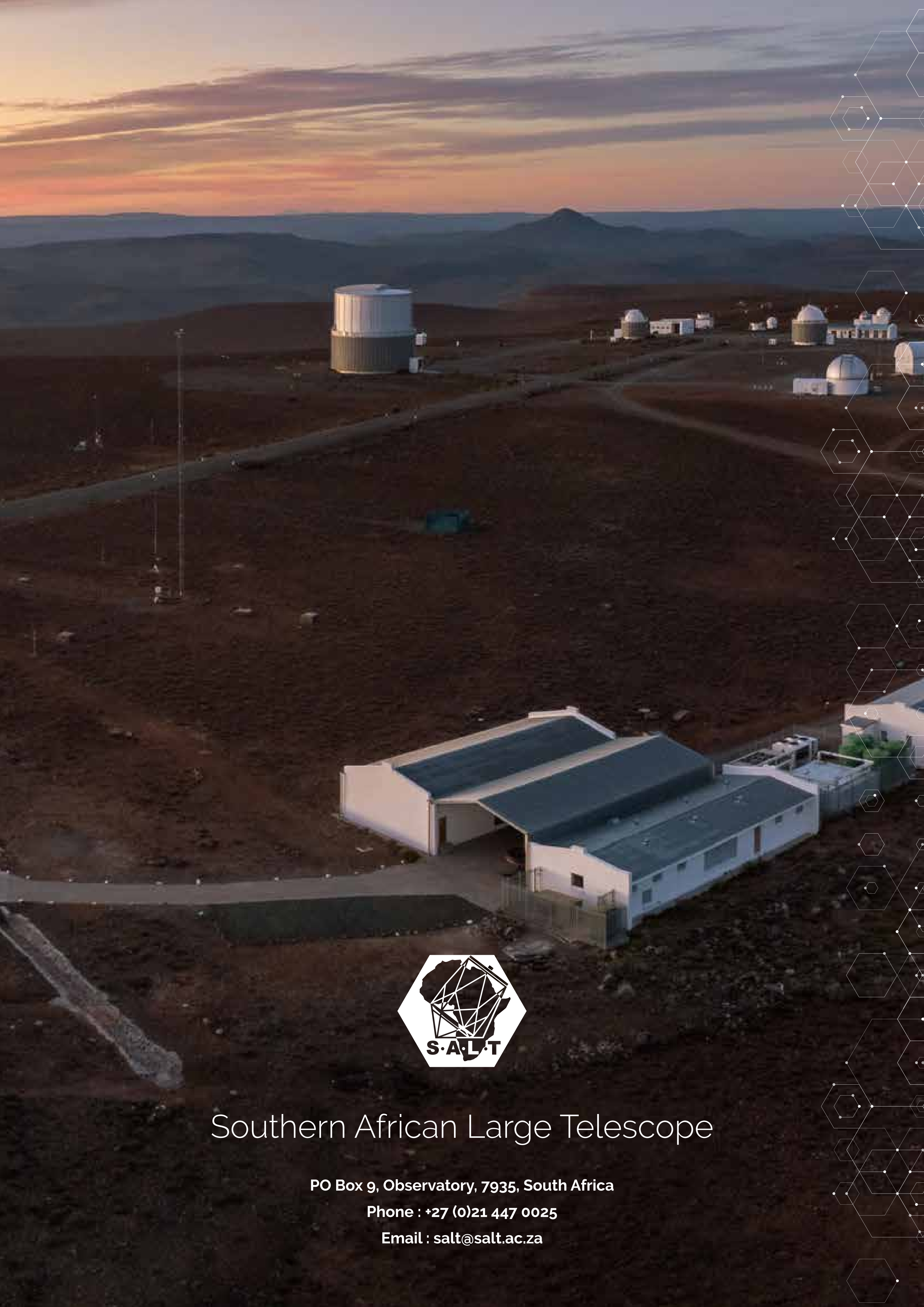
19 May

SA: Encarni SO: Veronica

I connected to SAMMI through RDP tonight, and I could hear HRS. SAMMI is also a lot more responsive through RDP.

22 May

Internet nightmare from Encarni's home at the beginning of the night. Dropping the connection every 5 mins. Ros came to the rescue while I tried multiple solutions – eventually it seemed to settle down at 9pm. THANK YOU ROS! :)



Southern African Large Telescope

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ABOUT SALT

The Board of the Southern African Large Telescope (SALT) is proud to present its Annual Performance Report for the period 1 January 2020 to 31 December 2020. 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.

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 two 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 ~36 percent stake. Other large shareholders are the University of Wisconsin–Madison ("UW"), the Nicolaus Copernicus Astronomical Centre of the Polish Academy of Sciences ("POL"), Dartmouth College ("DC") and Rutgers University ("RU"). Smaller shareholders include the Indian Inter–University Centre for Astronomy and Astrophysics in India ("IUCAA"), the American Museum of Natural History ("AMNH"), the University of North Carolina ("UNC"), which left the consortium in 2020. and the UK SALT Consortium ("UKSC"), with the latter representing the Universities of Central Lancashire, Keele, Nottingham, 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. Two of the original shareholders, Göttingen University (Germany) and the University of Canterbury (New Zealand), 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 And Mission

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

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.

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).

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.

CHAIRMAN'S OVERVIEW

"SALT was brought back to full remote operations on 8 May, just about six weeks after its closure… one of the first large telescopes worldwide to do so!"

2020 was a very challenging year for observatories worldwide, and SALT was no exception.

The spread of COVID-19 into South Africa was confirmed on 5 March, 2020, followed a few weeks later by countrywide shutdowns that lasted for months. By 24 March it had become impossible to operate SALT safely, and the decision was made to cease operations.

Fortunately, the idea of remote operations had been considered and prepared for for some time, and the Operations team only had to do a risk analysis to get the telescope back online after the stringent lockdown was over. Thus, SALT was brought back to full remote operations on 8 May, just about six weeks after its closure... one of the first large telescopes worldwide to do so! Remote operations remained the norm into 2021, and are likely to continue to be a major part of SALT science for the foreseeable future.

Two important pieces of telescope hardware were the subjects of much time and effort in 2020. The new mirror segment positioning system (SPS), which controls each of the 91 hexagonal 1 metre segments of the primary mirror, was successfully installed, tested and made operational. The transition was somewhat nerve-wracking, as there was no "going back to the previous system" possible. Fortunately, the transition was smooth, and the new SPS is performing extremely well. The large M3 mirror in the prime focus spherical aberration corrector was successfully cleaned after a decade of use, with a significant increase in telescope throughput being immediately obvious afterwards.

Extensive testing of the High Resolution Spectrograph's High Stability mode demonstrated stability to at least the 3 m/s level. Exoplanet science is thus feasible with SALT. Testing is ongoing, but on the basis of the preliminary results just noted, the SALT Board authorised the purchase of a Laser Frequency Comb for precision wavelength calibration for the HRS, to be delivered in 2022.

SALT and its twin, the HET, are the only 10-meter class telescopes with spherical primary mirrors. While this allowed SALT to be built for ~20% the cost of other telescopes of similar aperture, the downside is that large, heavy and expensive correctors are essential to remove SALT's and HET's optical aberrations. But the spherical primaries also permit targets distributed over an area of order 900 square degrees to be sampled simultaneously by SALT if "mini-trackers", coupled to science instruments, are strategically deployed beside the main tracker. If this were done, the main science programs of SALT, defined by the SALT consortium partners, would continue unabated. But up to four strategically chosen targets within about 15 degrees of the primary target could be observed simultaneously.

The Board authorised a preliminary study of the mini-tracker concept in 2020. The study demonstrated that up to four such mini trackers could, in principle, be deployed, to effectively quintuple SALT's science throughput. A detailed engineering study is ongoing, with a goal of having at least one working mini-tracker operational by the time that the large flow of astrophysical transients from the Vera-Rubin telescope begins.

SALT is looking for one new partner to join the SALT Consortium, and/or to sell "guaranteed success" observing time. Operations costs are 3–5 times lower than that of any telescope of comparable aperture.

Prof. Michael Shara
Chairperson, SALT Board

The current telescope capabilities are summarised at: https://astronomers.salt.ac.za/partner-opportunities/

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 ~$2890/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 ~$3 854/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 (~$9.1M) to support significant second-generation instrumentation development. Interested parties should contact the chair of the SALT Board of Directors, Michael Shara.

* 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-third 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 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 package, 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 SKA/MeerKAT initiatives spurring much of this growth. There are now over two hundred PhD astronomers at institutes around the country and students at all levels of study. Students are actively encouraged to participate in SALT projects and to propose for time on SALT. The entire South African community has access to SALT, and scientists from national research facilities and universities across the country use SALT regularly. South African researchers are active across a wide range of the multi-wavelength astronomy domain. In particular, 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, that is, a range of highly energetic phenomena (including exciting events such as the 2017 multi-messenger gravitational wave discovery) 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.

SALT Board members:
Molapo Qhobela, National Research Foundation
Shazrene Mohamed, SAAO/SALT

University of Wisconsin–Madison (USA)

The astronomy department group on top of their building.

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. Wisconsin is now building a near-infrared spectrograph for SALT in its Washburn Laboratory. Wisconsin astronomers use SALT to understand the kinematics and distribution of ionised gas in and around galaxies, redshift surveys to measure the distribution of mass in galaxy clusters, surveys of galaxies at intermediate and high redshifts, as well as high-resolution studies of stellar variability.

SALT Board members:
Matthew Bershady

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 program began in the 1990s with the addition of a number of research-active astronomers and an increase in the number of graduate students. At the end of the decade, Rutgers joined the SALT consortium. Today the astronomy group includes ten faculty, two research scientists, three postdoctoral associates, and 19 graduate students.

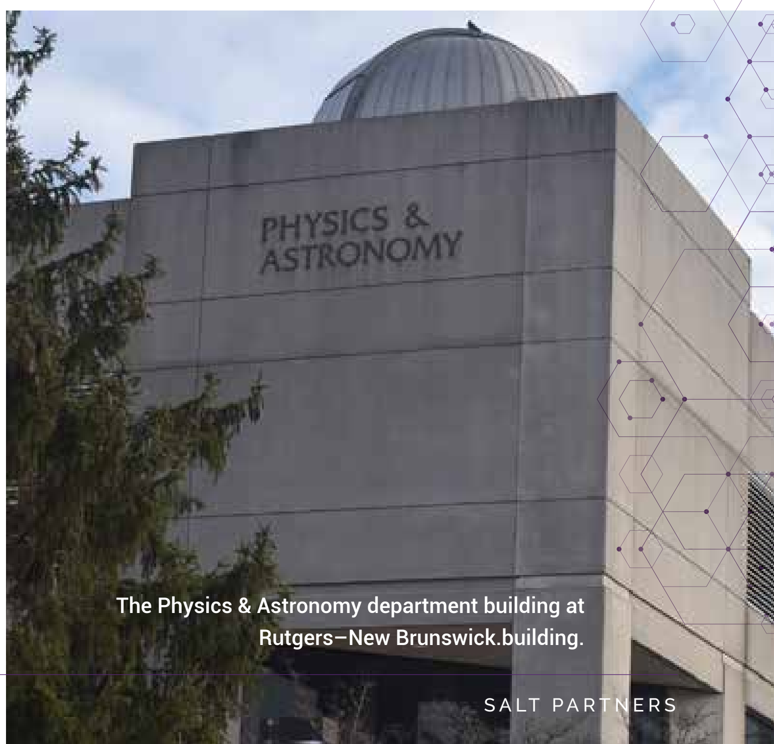
Rutgers' astronomers, led by Prof. Ted Williams, participated in the design, development and fabrication of the Robert Stobie Spectrograph (RSS) and led the effort to build the Fabry–Pérot Imaging Spectrophotometer subsystem. Williams and his colleagues utilised this instrument to carry out the RSS Imaging spectroscopy Nearby Galaxies Survey (RINGS) of nearby, normal galaxies to characterise their structure using measurements of Hα velocity fields.

Prof. Saurabh Jha uses SALT/RSS to study supernova explosions, observing mostly type Ia, or thermonuclear, supernovae to investigate their nature and, more broadly, to answer key questions in SN Ia cosmology. In 2017, Jha started a new project to measure binary orbital parameters of a sample of candidate white dwarf binaries with the HRS.

SALT Board members:
Jack Hughes

The main area of Prof. John P. Hughes' research focuses on the astrophysics of supernova remnants. Current student Prasiddha Arunachalam is using coronal iron line emission from RSS observations to study ejecta properties in the full sample of known SN Ia remnants in the Large Magellanic Cloud. In collaboration with colleagues in South Africa, Hughes has made dynamical mass measurements of galaxy clusters from the ground-based Atacama Cosmology Telescope to aid in precise cluster mass calibration for constraining cosmological parameters. He has also used SALT for confirmation and redshift measurement of Planck cluster candidates.

Prof. Andrew Baker is involved in two large SALT collaborations: the "SALT Gravitational Lensing Legacy Survey" targets submm-bandsub-mm-band sources from the Herschel space mission that are likely high-redshift ($z \sim 2 - 4$), gravitationally-lensed star formingstar-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–PICo-PI of the LADUMA radio survey with the South African MeerKAT array to study the evolution of neutral gas in galaxies over cosmic time. In other, related work, Baker's current graduate student John Wu is studying star formation in massive galaxy clusters using the RSS Fabry–Pérot instrument.



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

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 European and International astronomical organisations. Currently, about 250 astronomers are employed in six separate university institutes and two institutes of the Polish Academy of Sciences (PAS). Some of them partnered to form the Polish SALT Foundation which has a 10% share in the construction and running costs of SALT. The Nicolaus Copernicus Center (CAMK) is the Polish coordinator for the project. Marek Sarna of CAMK is Poland's Board director and has been highly active in the Board and other SALT committees. Joanna Mikołajewska is a member of the STC, being highly involved in this and other SALT committees. There are five main SALT partner institutions in Poland.

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. At present, 57 scientists are working at CAMK along with 35 PhD students. Astronomers at CAMK are involved in a number of major international observational projects (e.g., CTA, Herschel, SALT), and are actively collaborating with scientists all over the world. Collaborations on SALT science include SAAO and the American Museum of Natural History. The main SALT research interests are: the search for symbiotic stars in the Milky Way and the Magellanic Clouds and the study of individual systems; novae; post AGB binaries and dark matter studies using spectroscopic long term monitoring of selected quasars. Prof. J. Mikołajewska leads SALT HRS monitoring of Magellanic symbiotic stars and Galactic recurrent novae where the focus is the determination of the first-ever spectroscopic orbits to measure masses of both components. Prof. B. Czerny from the Center for Theoretical Physics PAS leads long term monitoring of broad emission lines coming from AGNs.

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, playing an important and active role in the European LOFAR collaboration. The main scientific programs that use SALT data are 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 is located in Piwnice village, 15 km north of Toruń, and is home to a VLBI station and a few optical instruments. The optical telescopes are used mainly for student training and modest research projects. SALT researchers here 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 (in Poland and in 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 research topics include dynamics of artificial satellites and space debris, studies of Small Solar System Objects, stellar astrophysics, dynamics of star clusters, radio and IR observations of gas and dust in galaxies. 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 and on pulsating stars (using asteroseismology). Observations are conducted with a coronagraph located near Wrocław and with SALT (among others), respectively. Satellite observations also play an important role in these investigations.

SALT Board member:
Marek Sarna, CAMK

NICOLAUS COPERNICUS UNIVERSITY IN TORUŃ

Dartmouth College (USA)

Astronomy group photo taken in front of the Shattuck Observatory on campus.

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 four faculty members, three post-doctoral fellows and about ten graduate students.

SALT Board member:
Brian Chaboyer

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 utilised by IUCAA members 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.

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 NIR spectrograph.

SALT Board member:
Somak Raychaudhury

View of IUCAA's campus.

UK SALT Consortium

An early and enthusiastic supporter of the SALT project, the UK's consortium (UKSC) consists of six astronomy groups, all of whom have had a long-standing involvement with astronomers in South Africa (SA), including providing support for visiting graduate students and postdocs to SA. Furthermore, UKSC has successfully hosted a half-dozen SALT Stobie scholarships, greatly enhancing the production of SA astronomy PhDs. Since 2018, the consortium has been able to use its "Global Challenges" research funding to support SA post-docs to visit the UK for extended periods. 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.

University of Central Lancashire

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 also been highly active in other SALT committees (e.g. FAC, BEC, SSWG). UCLan has made extensive contributions to the SALT Collateral Benefits Programme (SCBP), has hosted successful SALT Stobie scholarships, and has provided UCLan's distance learning university-level Astronomy courses (at discounted rates) for SALT engineers, operators and other staff for more than 10 years, as well as supporting visiting graduate students. Their SALT science interests involve collaborations within UKSC (with Keele and Armagh) and with SA, in particular with NWU and SAAO.

Open University

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 studied dust from catastrophically disintegrating planets (such as Kepler 1502b), to studies of variable star populations and unique individual variables from SuperWASP (A. Norton, M. Lohr). Norton has recently focussed on following up a set of close-contact red giant eclipsing binary candidates which may be red nova progenitors. S. Serjeant and L. Marchetti (UCT) coordinate the "SALT Gravitational Lensing Legacy Program" to pioneer a major new strong gravitational lens selection method, combining Herschel Space Observatory wide-area sub-mm observations with multi-wavelength ancillary data, generating the largest (> 500) sample to date of homogeneously selected lens candidates and obtaining SALT spectroscopy for most of them.

Armagh Observatory

SALT science at Armagh Observatory 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. They have collaborations within UKSC and with SA (SAAO, UCT and UWC). People involved at Armagh are S. Jeffery, M. Burton, G. Ramsay, J. Vink and G. Doyle, and have recently been enhanced with the arrival of M. Sarzi who is taking on the role of representing Armagh on UKSC.

Keele University

At Keele University, J. van Loon's interests in SALT have been to exploit the RSS Fabry–Pérot mode to map emission as well as absorption features in nearby galaxies, and long-slit spectroscopy of various types of stars and of a peculiar AGN.

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

University of Nottingham

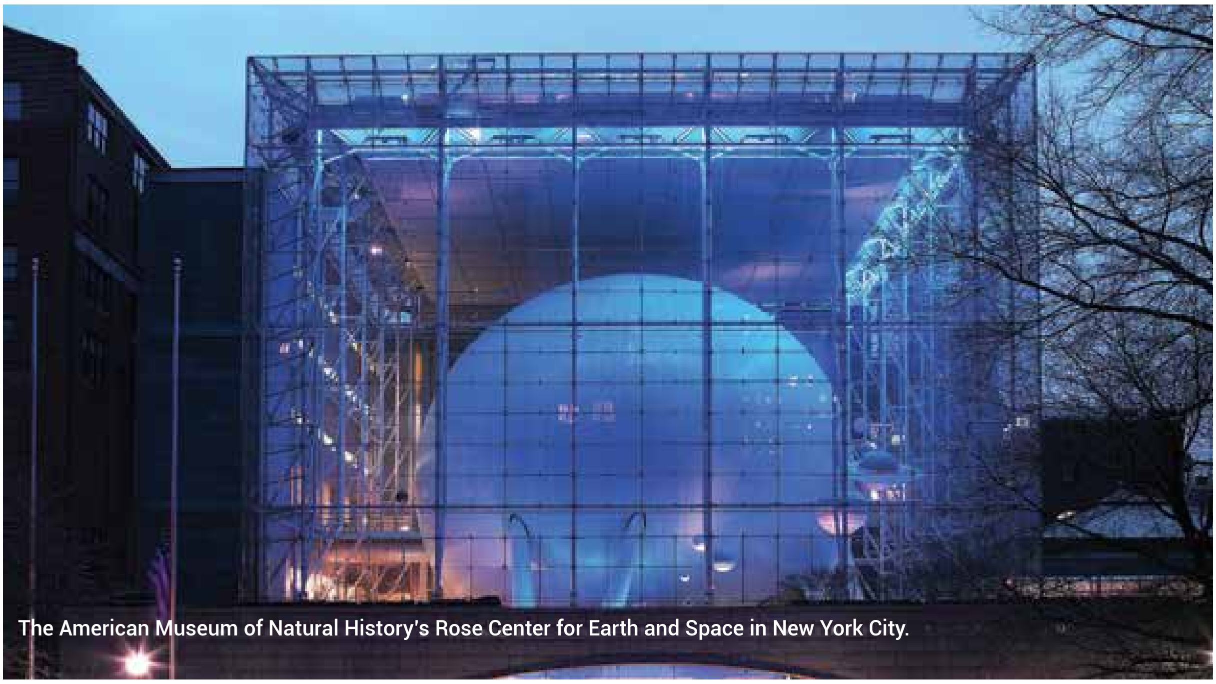
The University of Nottingham has had significant involvement in SALT administration (UKSC Board director for four years and Chair of the FAC for three years), as well as funding a post-doc (six months) and two graduate students (two months each) to work on technical and software development for SALT in its early years. Science interests (P. Sarre) are in molecular astrophysics and galaxies, making observations with RSS (long-slit and Fabry–Pérot) and HRS.

University of Southampton

P. Charles from the University of Southampton (current UKSC Board director for SALT) was SAAO Director for 7 years and, together with many of the Southampton Astronomy Group, is actively involved in the SA-led SALT Large Science Programme "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. The Astrosat observations include another major SALT partner, India. 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 weekly Swift's S–CUBED monitoring (M. Coe). Also interested in SALT science are C. Knigge, D. Altamirano, T. Bird and P. Gandhi.

SALT Board member:
Phil Charles, University of Southampton

The American Museum of Natural History (USA)


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

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 program 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.

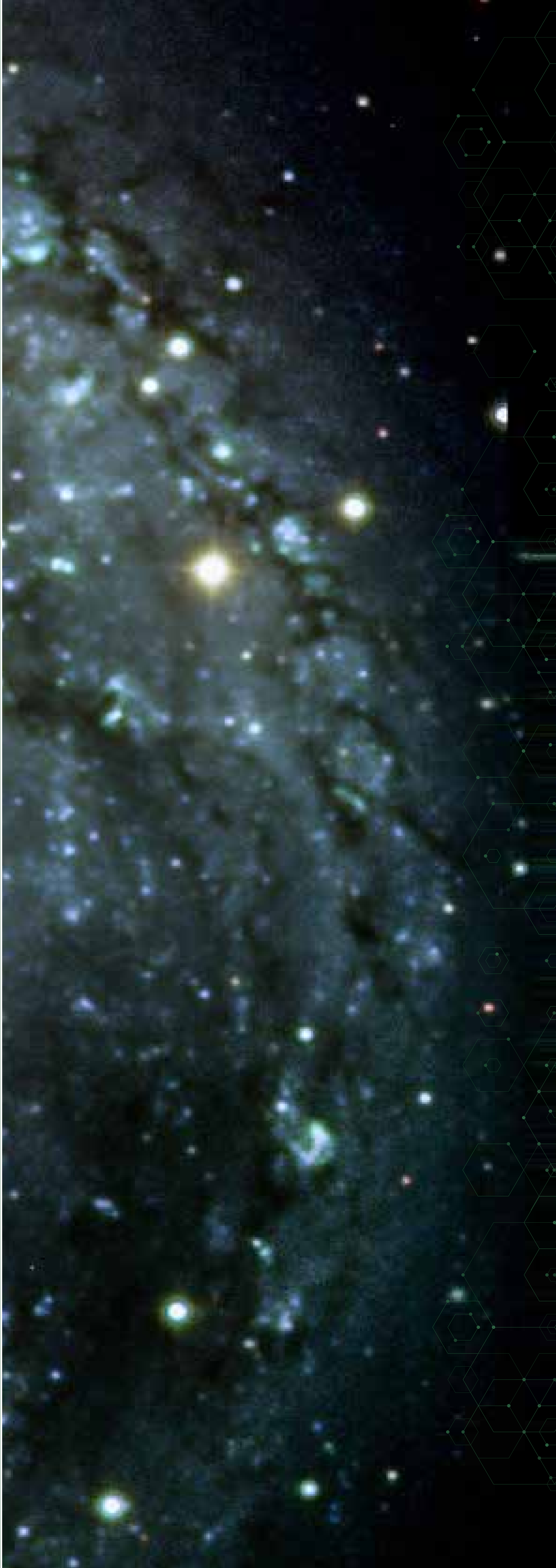
Astronomy has been part of AMNH since the opening of the Hayden Planetarium, partly funded by philanthropist Charles Hayden, in 1934. The completely rebuilt Planetarium, opened in 1999, is a 30-m diameter sphere inside an 8 story-high glass cube, which houses the Star Theater. The theatre uses high-resolution 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 continues to serve in that position. Prof. 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.

Shara recently published an HRS-based paper reporting on the spin rates of O stars in Galactic and O+WR binaries. The O stars spin, on average, at half their breakup speeds, much less than mass transfer in these binaries suggests. An efficient method of shedding angular momentum is clearly at work. AMNH Postdoctoral Fellow Sam Grunblatt has initiated an HRS study of hot, southern exoplanet candidates identified with TESS. University of Cambridge PhD student Laura Rogers (in collaboration with Shara) continues to use SALT/HRS to characterise white dwarfs heavily polluted with metals, probably via accretion of asteroids and dust.

SALT Board member:
Michael Shara (chair)

SCIENCE HIGHLIGHTS



SCIENCE HIGHLIGHTS

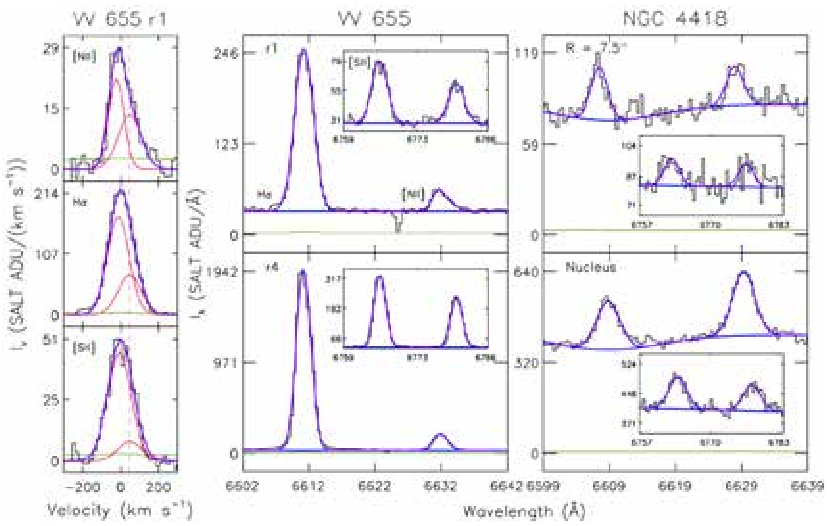
extragalactic astronomy

VV 655 and NGC 4418: Minor interactions can affect the evolution of a LIRG

SALT/RSS observations helped to explore the role of a minor interaction in shaping the evolutionary trajectory of a massive galaxy, using the NGC 4418/ VV 655 system as a case study. This low-redshift galaxy pair (z ~ 0.007) consists of a lenticular luminous infrared galaxy (LIRG), NGC 4418, that shares H I tidal debris with its gas-rich, dwarf irregular companion, VV 655. NGC 4418 displays an unusually compact nucleus. A bipolar outflow appears to be driven from this central concentration of molecular gas and dust. Erin Boettcher (UW) and her team investigated the role of the interacting dwarf companion in shaping the unusual nuclear properties of the LIRG.

The authors characterised the chemical and kinematic properties of the warm ionised gas associated with these galaxies using optical emission-line spectroscopy from SALT/RSS in long-slit mode and SDSS-III DR12 single-fibre observations. Using strong-line diagnostics, they estimated a gas-phase metallicity of 40 – 60% of solar across VV 655 but close to solar in the body and ionised outflow of NGC 4418. This suggests that any gas transferred from the dwarf galaxy to the LIRG has resided in the massive galaxy for long enough to become chemically enriched. A redshifted velocity wing in the [N II] λ6583 emission line indicates gas at anomalous velocities (v ≤ 100 km/s) near star-forming regions in VV 655 (see figure). This suggests that stellar feedback may drive outflows or a galactic fountain, making the dwarf galaxy more susceptible to gas stripping in interactions.

Boettcher and her co-authors concluded that tidal torquing, inducing an internal migration of the interstellar medium of NGC 4418 by VV 655, is the most likely explanation for the unusual nuclear properties of the LIRG. A gas transfer scenario between the two galaxies is unlikely; models suggest that this process is inefficient, likely requiring an order of magnitude more H I associated with VV 655 than is observed to produce the approximately 10^9 solar masses of gas present in the centre of the LIRG. This is consistent with the different gas-phase metallicities of the galaxies and the lack of evidence for disturbance in the ionised gas kinematics along the minor axis of NGC 4418. This case study illustrates that minor interactions can have a significant impact on the evolutionary pathways of massive galaxies.



SALT/RSS spectra for a diffuse (r1) and a star-forming region (r4) in VV 655, and near the nucleus and at an offset of R = 7.5'' to the NW in NGC 4418. Right: redshifted velocity wing in r1. Blue and purple lines are fits to the continuum and the Gaussian profiles, respectively. Green curves are error spectra. The difference in [N II] λ6583/Hα of about an order of magnitude between the galaxies suggests that the metallicity of the outflowing, ionised gas in NGC 4418 significantly exceeds that of the H II regions in VV 655.

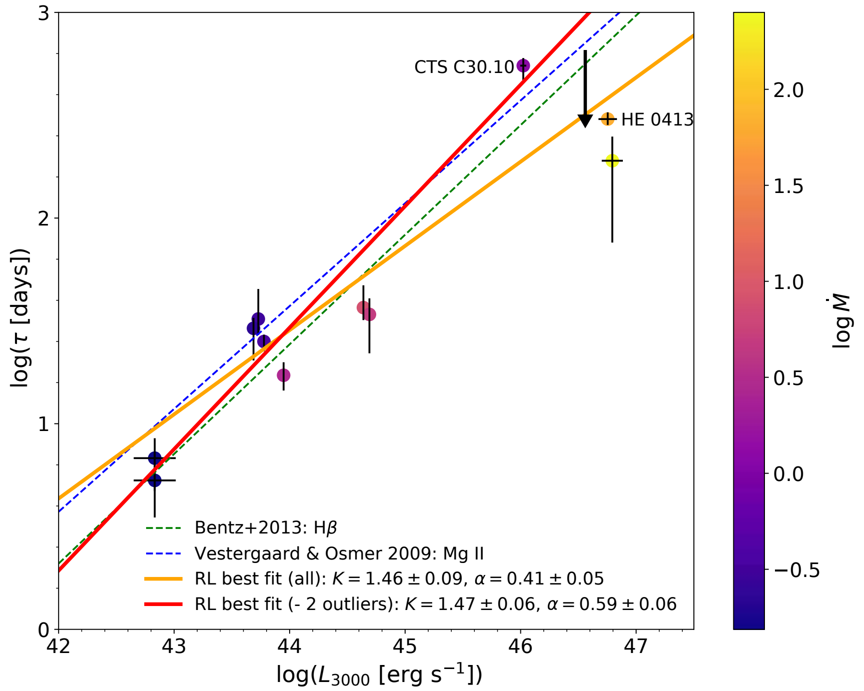
Boettcher, E., et al., 2020/05, A&A 637, A17: VV 655 and NGC 4418: Implications of an interaction for the evolution of a LIRG

The highly accreting quasar HE 0413–4031 and the Mg II-based radius-luminosity relation

The relation between the size of the broad-line region in active galactic nuclei and the monochromatic luminosity, the so-called radius-luminosity (RL) relation, plays a vital role in astrophysics. First, it can be applied to determine supermassive black hole masses across the cosmic history just from one spectrum, which has an importance in the study of the structure formation in the Universe. Second, it has been playing an increasing role in cosmology since the RL relation can be used to determine luminosity distances of quasars, which can be observed up to a redshift of almost seven, which is much earlier in cosmic history than what supernovae of type Ia can probe.

The RL relation for the broad Hβ line has been extensively studied. Over the years, with more reverberation-mapping measurements, the scatter of the Hβ-based RL relation has increased considerably. It was found that the departure from the mean RL relation is the largest for the highly accreting sources, i.e., sources that accrete gas and dust close to the Eddington limit.

However, the Hβ sample of galaxies is generally limited to sources with a redshift of less than one. To go beyond, one needs to look at broad UV lines, with the Mg II line being the most prominent. Thanks to the long-term monitoring by SALT, the team led by B. Czerny (POL) could determine the time-delay for a high-luminosity quasar CTS C30.10, which helped to recover an analogous RL relation for the Mg II line as well as for the Hβ line (as reported in the SALT Annual Report 2019). This year, the team, this time led by Michal Zajaček, obtained results for a second source, the high-luminosity and highly accreting quasar HE 0413-4031, which was also monitored by SALT over the previous six years. The new result shows that, as for the Hβ sample, the scatter along the Mg II-based RL relation is mainly driven by the accretion intensity. With the rest-frame time delay of about 300 days, HE 0413-4031 has, however, a shorter time delay than expected from the RL relation. Further constraints for the RL relation based on the Mg II line and thus for higher-redshift sources will open a way to use this relation for cosmological applications.



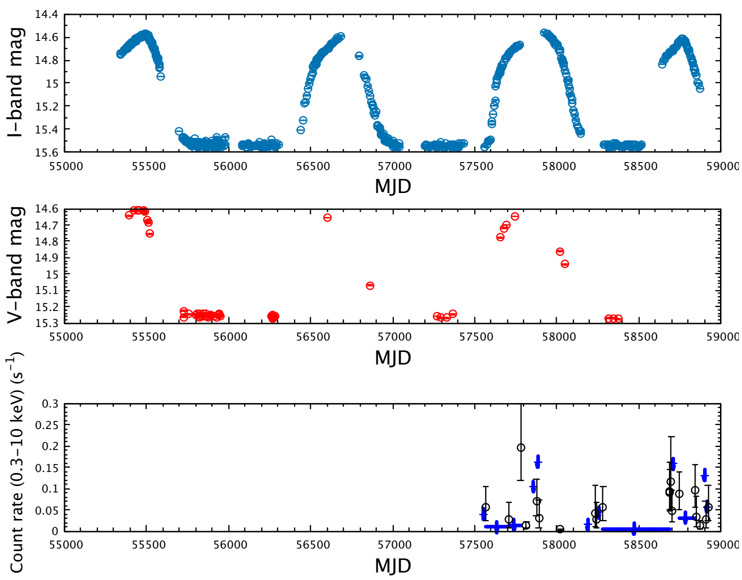
Radius-luminosity relation for Mg II reverberation-mapped sources, including CTS C30.10 and HE 0413-4031, as monitored by SALT. Each source is colour-coded according to the dimensionless accretion rate. HE 0413-4031 lies below the best-fit relation as well as previously published relations. This is also the case for all other higher-accreting sources. Hence, the scatter along the RL relation seems to be driven by the accretion-rate intensity.

Zajaček, M., et al., 2020/06, ApJ 896, 146: Time-delay Measurement of Mg II Broad-line Response for the Highly Accreting Quasar HE 0413-4031: Implications for the Mg II-based Radius-Luminosity Relation

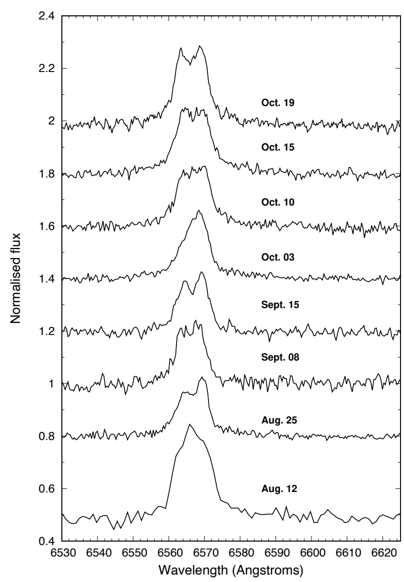
SALT monitors a peculiar Be X-ray binary in the Small Magellanic Cloud

Be X-ray binaries (BeXBs) are a subclass of high-mass X-ray binaries and are made up of a compact object (primarily a neutron star) in an eccentric orbit around a Be star. The Be star has a variable, geometrically thin Keplerian disc which supplies the matter that accreted by the neutron star resulting in X-ray outbursts. Depending on the luminosity, the X-ray outbursts can be classified as type I ($L_X < 10^{37}$ erg/s) or type II ($L_X > 10^{37}$ erg/s). Be stars are characterised by infrared excess and emission lines in their optical spectra. Both of these observational features are signatures of the presence of the disc around the Be star.

Our neighbouring irregular dwarf galaxy, the Small Magellanic Cloud (SMC), has an overabundance of BeXBs. The low foreground extinction and a well-defined distance make the SMC an ideal laboratory to study these binaries. The SMC is monitored in the X-rays by the Swift SMC Survey (S-CUBED). S-CUBED is a high-cadence survey that covers the optical extent of the SMC and consists of 142 tiled pointings performed weekly. The authors studied one target in the S-CUBED catalogue, XMMU J010331.7-730144 (hereafter X0103), which undergoes large repeated optical outbursts as seen from observations performed with the Optical Gravitational Lensing Experiment (OGLE). During its most recent outburst, the team led by Monageng obtained a SALT/RSS spectrum of the source. The blue-end of the spectrum permitted the authors to classify the spectral type of the optical companion as O9.7–B0 IV-V. The broad-band spectrum revealed the Hα line in emission for the first time for this source, confirming its BeXB nature. X0103 was monitored further with SALT using spectra covering the Hα line region to study the evolution of the Be disc (right figure). The resultant equivalent widths evolve synchronously with the photometric emission from OGLE since they both originate from the disc. Given the amplitude of the photometric outbursts, however, the equivalent width measurements are surprisingly very low. Another peculiar feature about X0103 is its weak X-ray emission as seen in the S-CUBED dataset. The authors explain these observational mysteries by invoking a qualitative model that describes the variability as due to the Be disc density and opacity changing rather than its physical extent as a result of efficient truncation by the neutron star.



Long-term OGLE I-(top panel) and V-band (middle panel) magnitude variability. The Swift X-ray variability from the S-CUBED programme is shown in the bottom panel, where the blue arrows indicate the upper limits and the black circles show the detections.



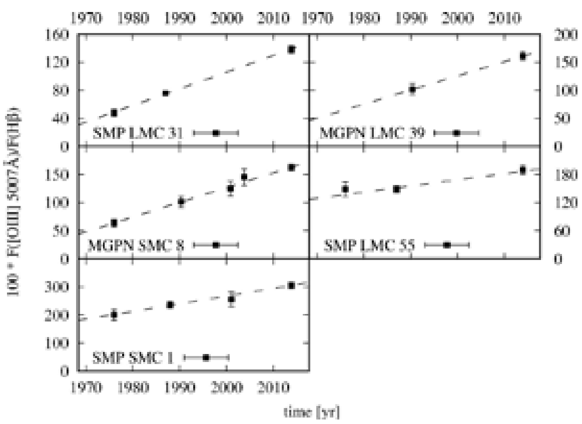
Evolution of the Hα equivalent width from SALT observations obtained in 2019 during the latest OGLE outburst.

Monageng, I.M., et al., 2020/08, MNRAS 496, 3615:
Optical and X-ray study of the peculiar high-mass X-ray binary XMMU J010331.7-730144

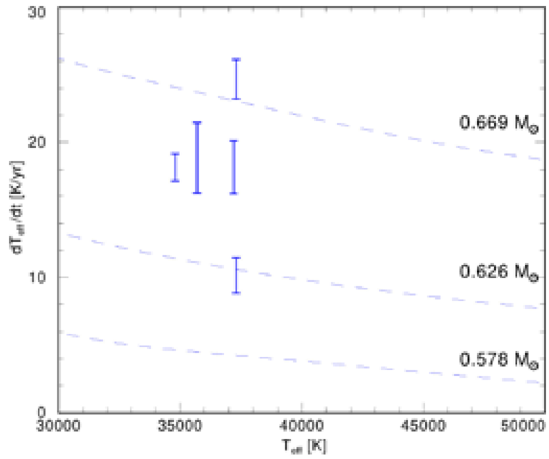
Rapid evolution of [WC] stars in the Magellanic clouds

[WC] stars are central stars of planetary nebulae that are H I deficient and show emission line spectra typical for Wolf-Rayet (WR) stars of the carbon sequence. Marcin Hajduk (POL) decided to study the changes in the [O III] 5007Å/Hβ line flux ratios in planetary nebulae in the Magellanic Clouds. He used spectra of 14 nebulae obtained with SALT/RSS in 2013. He found a linear increase of the [O III] 5007Å/Hβ line flux ratio with time for five of the nebulae. These nebulae probably host the most massive central stars in the observed sample. The remaining objects evolved too slowly to show an observable evolution of the [O III] 5007Å/Hβ line flux ratio.

The author ran the Cloudy photo-ionisation models to fit the observed evolution of the [O III] 5007Å/Hβ line flux ratio in the five nebulae to determine the heating rate of their central stars. The observed sample contained one known [WC] star, MGPN SMC 8, but it turned out that three other objects also showed emission lines characteristic for [WC] stars: SMP LMC 31, SMP LMC 55 and SMP SMC 1. The determined rate of temperature change for these stars is between 10 and 25 K/year. The masses of the [WC] stars determined by interpolation of evolutionary tracks cover the range of 0.613–0.693 $M_\odot$. The mass of the star, which does not show emission lines, is 0.57 $M_\odot$.



Observed evolution of the [O III] 5007Å/Hβ line flux ratio in Magellanic Cloud planetary nebulae.



Heating rates for the five central stars in Magellanic Clouds and three helium-burning post-AGB evolutionary tracks for different masses.

The rapidly evolving [WC] stars are brighter than stars without emission lines, as determined previously in the literature by modelling the observed spectral energy distribution as well as by the using the Zanstra method. This provides an independent confirmation that the [WC] stars in the Magellanic Clouds are more massive than the hydrogen-rich central stars.

Further research has shown that the maximum of the mass distribution for white dwarfs of the DA type is 0.598 $M_\odot$, while for dwarfs of the DB type, which may be the final product of stellar evolution [WC], it is 0.651 $M_\odot$. This fits very well with the masses that the author obtained for the four stars [WC] in the Magellanic Clouds. It has been shown that [WC] stars are located closer to the Galactic plane, which also supports their larger mass, in line with the results presented here. In turn, the masses of hydrogen-rich central stars are significantly lower than those of DA dwarfs.

Massive post-AGB stars (final mass $M_f > 0.6\ M_\odot$) do not expand significantly due to the H-ingestion flash (HIF). The energy released when the hydrogen layer is burnt is lower than the envelope binding energy. Massive stars should return to the AGB region only once as a result of a very late thermal pulse. This process could be responsible for the formation of most [WC] stars.

Hajduk, M., 2020/10, A&A 642, A71: Rapid evolution of [WC] stars in the Magellanic Clouds

SCIENCE HIGHLIGHTS

stellar and Galactic astronomy

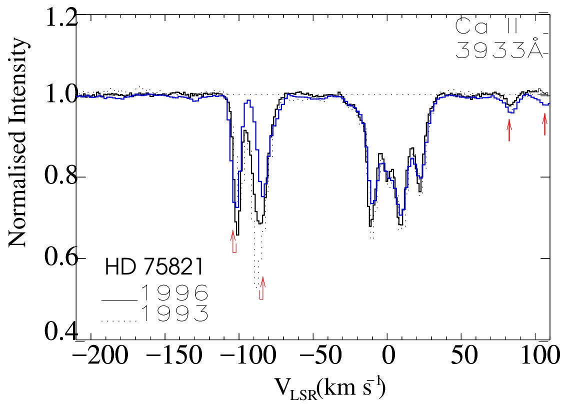
Variability of interstellar lines in the direction of the Vela supernova remnant

The Vela supernova remnant (SNR) is a young, 11,000-year old remnant close to Earth at a distance of 287 ± 19 pc with a linear diameter of 40 pc. With its large angular size and youth, this SNR provides a fine opportunity to probe aspects of the interaction of an energetic remnant with its surrounding interstellar medium (ISM). One method of probing the interaction is through absorption spectroscopy of optical lines such as the Ca II H & K and Na I D lines along lines of sight towards stars in and behind the SNR. In particular, the monitoring of the strengths and velocities of these absorption lines, especially the stronger H & K lines, is likely to reveal details about the SNR's evolution and its interaction with the local ISM.

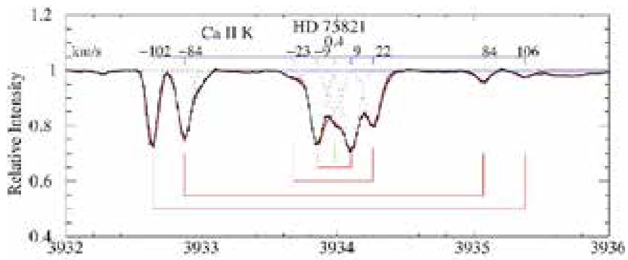
During 2017–2019, Neelamraju Kameswara Rao and his colleagues obtained high-resolution optical spectra with SALT/HRS of 15 stars in the direction of the Vela SNR which showed that variations in the interstellar Ca II H & K line profiles and, to a lesser extent, in the Na I D line are a common occurrence. In particular, the SALT line profiles are compared with profiles of a comparable spectral resolution obtained at ESO in 1993–1996 by Cha & Sembach. A typical timescale for variations is a few years, and small angular separations between stars may also display appreciable profile differences either in radial velocity or equivalent width or both. There is now evidence for clouds moving into a line of sight or being created. Acceleration of clouds has been observed as well, particularly near the edge of the SNR.

The present study also shows some puzzling sets of absorption components indicating complicated velocity patterns (e.g., HD 75821, see figure). A most striking change occurs in the −85 km/s component which weakened greatly from 1993 to 1996 but less severely from 1996 to 2017. A tantalising aspect of the K line complex of components is the symmetry of velocities about a central component at 0.4 km/s. The velocity structure may speculatively link whirlwinds along the line of sight.

Detailed and repeated observations of more lines of sight covering the 8-degree wide SNR would be of interest: extending our sample from 15 to the 68 sight lines covered by Cha & Sembach is likely needed to understand the mode of ejection of the supernova material and kinematics of the SNR. Since optical absorption line spectroscopy provides few probes of an SNR, where temperatures and pressures may be considerably higher than in the undisturbed ISM, UV spectroscopy is also needed. A clear impression gained from UV and the optical observations and theoretical analysis are that of gas shocked by the supernova. Although the description of the physical conditions demands additional UV spectroscopy, illumination of the temporal and spatial variations is better pursued with optical spectroscopy where telescope time is more freely (and cheaply) available than from space.



Comparison of the Ca II K profile from the HD 75821 sight-line obtained with SALT in 2017 (blue) with the literature (black).



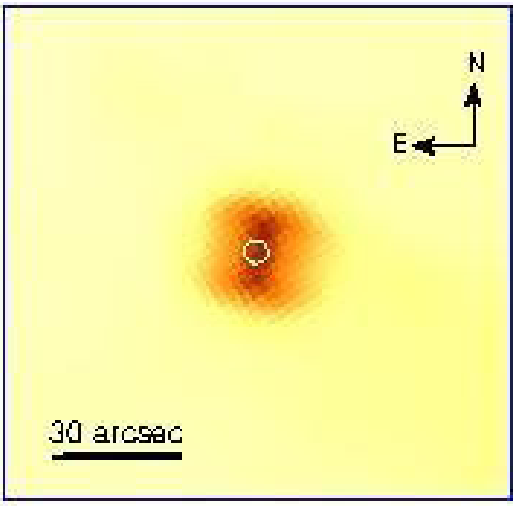
Ca II K profile with Gaussian fits to the various components. Note the symmetric velocity spacing of components from the central component at 0.4 km/s (green line). Four pairs of equal negative and positive radial velocity components are indicated (blue line and red bracketts).

Kameswara Rao, N.R., et al., 2020/01, MNRAS 493, 497: Unveiling Vela – variability of interstellar lines in the direction of the Vela supernova remnant – III. Na D and Ca II K

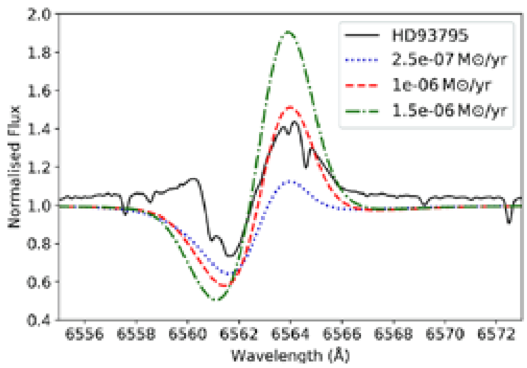
HD 93795: a late-B supergiant star with a square circumstellar nebula

Vasilii Gvaramadze (SAI Moscow) and Alexei Kniazev (SAAO/SALT), together with their collaborators, have reported the discovery of a compact infrared nebula around the emission-line star HD 93795 using archival data from the Spitzer Space Telescope. Follow-up optical spectroscopy of HD 93795 with SALT/RSS led to its classification as a B9 Ia star, while modelling of its spectrum showed that HD 93795 is a relatively unevolved star moving redward for the first time. These findings support the previous view that massive stars can produce circumstellar nebulae while they are still on the main sequence or shortly after they left it.

The nebula has a square shape with a bright ridge in the middle and two symmetric flanks perpendicular to the ridge. It was suggested that the ridge is an axially symmetric flattened structure viewed edge-on and that the flanks outline the beginning of bipolar lobes. The axially symmetric shape of the nebula implies that HD 93795 was either a single fast-rotating star or a close binary system, which has merged in the recent past. In the first case, the only possible way to produce an axially symmetric nebula is through the rotationally induced bi-stability jump mechanism. The size and expansion velocity of such a nebula, however, would be much larger than those of the known circumstellar rings around blue supergiants. It was therefore concluded that the merger of binary systems is a more natural process leading to the formation of compact, slowly expanding and flattened circumstellar nebulae.



Spitzer 24 micron image of the nebula around HD 93795 (a white circle marks the position of this star). At the distance of 5 kpc, 30 arcsec corresponds to 0.72 pc.



Comparison of the observed profile of the Hα line (from the 2019 SALT/HRS spectrum) with synthetic profiles predicted by fastwind models with different values of the mass-loss rate as specified in the legend.

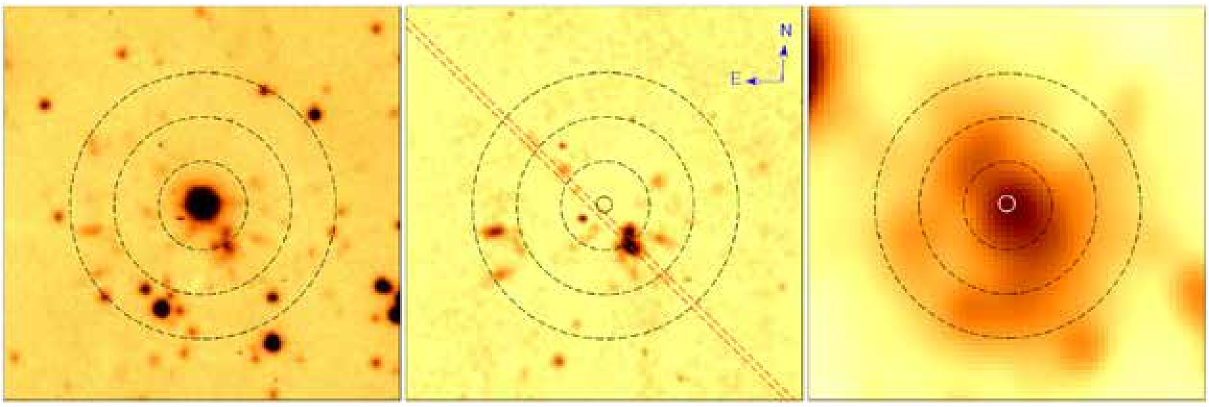
Gvaramadze, V.V., et al., 2020/02, MNRAS 492, 2383: HD 93795: a late-B supergiant star with a square circumstellar nebula

SALT finds hydrogen-poor knots in the planetary nebula WR 72

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

A team of astronomers led by Vasilii Gvaramadze of the Lomonosov Moscow State University, Russia, reports the discovery of hydrogen-poor knots in the central part of the planetary nebula around WR 72, a Wolf–Rayet star (classified as [WO1] due to its strong O VI emission lines). The study, using SALT/RSS as well as WISE data, shows that the WR 72 nebula consists of an extended, nearly circular halo (about 2.4 pc in diameter) and an elongated and apparently bipolar inner shell (around a factor of six smaller in size) that contains the hydrogen-poor knots. The observations identified a bright knot to the southwest from WR 72 and a number of faint knots scattered around the star. Some of the knots are elongated in the radial direction, as in the fan-like systems of hydrogen poor knots detected in the central regions of other PNe known as A 30 and A 78. The researchers found that typical radial velocity of the knots is 100 km/s.

These results suggest that the shell is about 1000 years old. More studies of the knots are required, especially deeper and higher-resolution spectroscopy and imaging, to determine their abundances and to check whether their spatial distribution and kinematics are axially symmetric. The detection of axial symmetry could mean that WR 72 is a binary system. The authors conclude that their findings indicate that WR 72 is a new member of the rare group of hydrogen-poor planetary nebulae, which may be explained through a very late thermal pulse of a post-AGB star or by a merger of two white dwarfs.



SALT [O III] 5007Å (left), continuum-subtracted (middle) and WISE 4.6μm (right) image of hydrogen-poor knots around WR 72. Concentric circles of radius 10", 20" and 30" are shown. At the distance of 1.42 kpc, 30" corresponds to ≈0.2 pc.

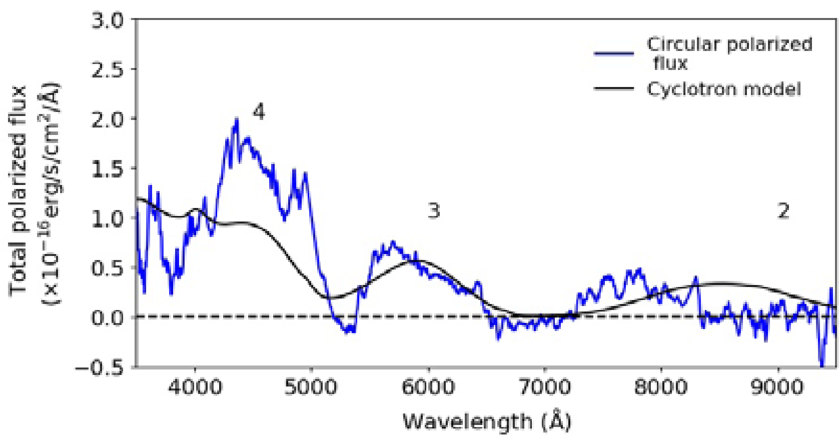
Gvaramadze, V.V., et al., 2020/03, MNRAS 492, 3316: WR 72: a born-again planetary nebula with hydrogen-poor knots

Simultaneous SALT and MeerKAT observations of the eclipsing polar UZ For

Cataclysmic variables are semi-detached, close binary systems consisting of a white dwarf (WD) accreting material from a low-mass main-sequence companion – usually a red or a brown dwarf. Cataclysmic variables are divided into two main groups, namely magnetic and non-magnetic systems. The magnetic systems are further divided into polars (or AM Her systems) and intermediate polars (or DQ Her stars). The WD in polars have a strong magnetic field and the two stars (the WD and the red dwarf) are tidally locked together in synchronous rotation. The presence of the strong magnetic field in the WD prevents the formation of an accretion disc and the materials in the ballistic stream is forced to first couple onto the magnetic field lines before being accreted on the surface of WD near the magnetic poles. The materials in the magnetically confined stream are first accelerated to supersonic speeds and this results in the formation of the strong shock above the surface of WD. The post-shock region in polars is responsible for the emission of cyclotron radiation observed in the optical and near-infrared. The post-shock region also emits hard X-rays and some of these are absorbed by the WD surface and re-emitted as soft X-rays and ultra-violet light.

UZ Fornacis (in short UZ For) is an eclipsing polar discovered as an X-ray source and subsequently classified as an AM Her system based on its optical spectrum and X-ray properties. It has an orbital period of 126.5 minutes and resides in the orbital period gap of the CV period distribution diagram. This source has been studied extensively in a wide range of wavelengths including optical, infrared, ultra-violet and X-rays. UZ For is one of few polars that is suspected to harbour extra-solar planets through the analysis of its mid-eclipse times.

Zwidofhelangani Khangale from UCT & SAAO and his colleagues report on the simultaneous optical and radio observations of the eclipsing polar UZ For conducted with SALT and MeerKAT. UZ For was observed with SALT/RSS in circular spectropolarimetry mode. The analysis of the circular spectropolarimetry data reveals broad emission features in the total intensity spectrum with a continuum that rises in the blue. The circularly polarized spectrum shows that UZ For is negatively polarized (up to ~ -8%) in the blue and decreasing gradually towards the red. In addition, the cyclotron spectrum of UZ For shows the presence of three cyclotron humps at ~4500 Å, 6000 Å and 7700 Å, corresponding to harmonic numbers 4, 3, and 2, respectively. These features are dominant before the eclipse and disappear after the eclipse. The harmonics are consistent with the magnetic field strength of ~57 MG seen at a viewing angle of 70 degrees. The MeerKAT radio observations show a faint source which has a peak flux density of 30.7 ± 5.4 μJy/beam at 1.28 GHz at the position of UZ For.



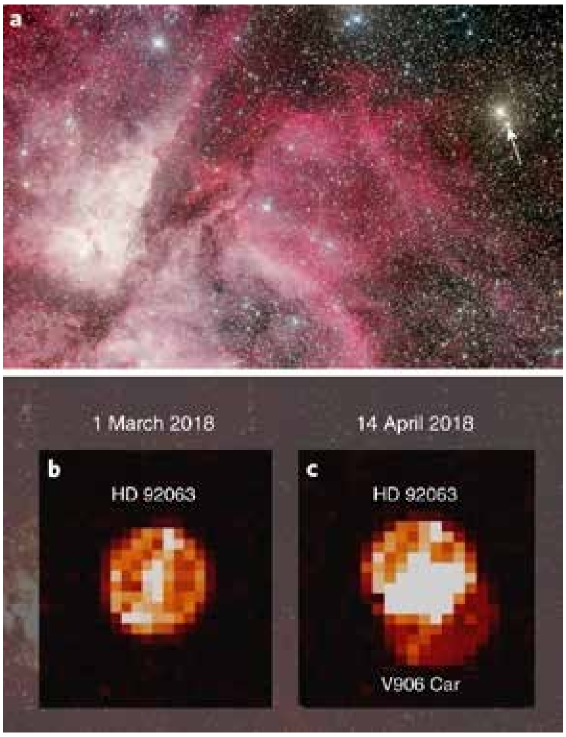
Total circularly polarized flux (blue) of UZ For centred at phase 0.91. Overlaid is the pure cyclotron model (black) with a magnetic field of 57 MG. The numbers 4, 3 and 2 mark the theoretical positions of the three harmonic features.

Khangale, Z.N., et al., 2020/03, MNRAS 492, 4298: A spectroscopic, photometric, polarimetric, and radio study of the eclipsing polar UZ Fornacis: the first simultaneous SALT and MeerKAT observations

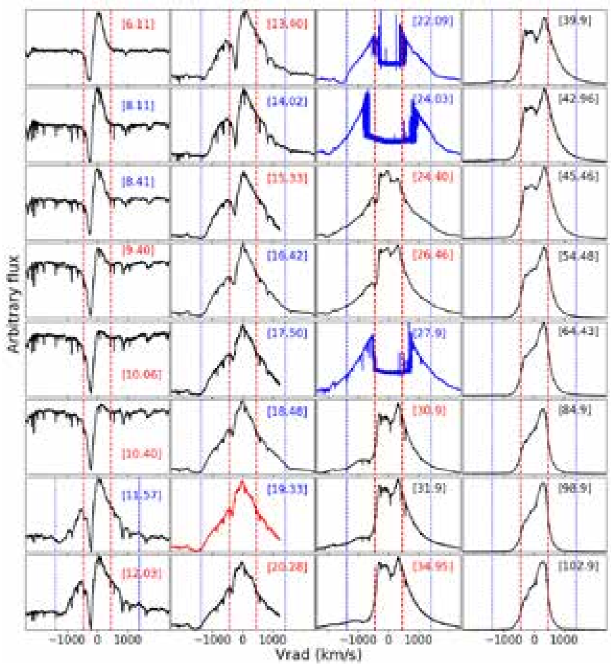
SALT contributes to a new understanding of novae

Classical novae are thermonuclear explosions that occur on the surfaces of white dwarf stars in interacting binary systems. It has long been thought that the luminosity of classical novae is powered by continued nuclear burning on the surface of the white dwarf after the initial runaway. However, recent observations of GeV gamma-rays from classical novae have hinted that shocks internal to the nova ejecta may dominate the nova emission. Shocks have also been suggested to power the luminosity of events as diverse as stellar mergers, supernovae, and tidal disruption events, but observational confirmation has been lacking.

An international team of researchers led by Elias Aydi, a former SAAO/UCT PhD student now at Michigan State University, presents simultaneous space-based optical and gamma-ray observations of the 2018 nova V906 Carinae (ASASSN-18fv), revealing a remarkable series of distinct correlated flares in both bands. The optical and gamma-ray flares occur simultaneously, implying a common origin in shocks. During the flares, the nova luminosity doubles, implying that the bulk of the luminosity is shock-powered. Furthermore, they detect concurrent but weak X-ray emission from deeply embedded shocks, confirming that the shock power does not appear in the X-ray band and supporting its emergence at longer wavelengths. High-resolution optical spectroscopy from different telescopes including SALT (taken under the transient follow-up programme, PI David Buckley from SAAO), allowed us to track the evolution of the eruption and the ejections of multiple flows at different speeds, which collided to form strong, radiative shocks. Our data, spanning the spectrum from radio to gamma-ray, provide evidence that shocks can power substantial luminosity in classical novae and other optical transients.



Nova V906 Car was discovered in a complex region of the Galaxy near the Carina nebula and the red-giant star HD 92063, which was being monitored by the BRITE satellite constellation. (a) V906 Car pictured in outburst and marked by a white arrow. HD 92063 is the brighter nearby star (credits: Maury & Fabrega). (b) BRITE image from before the outburst of V906 Car taken on 1 March 2018, showing only HD 29063. (c) BRITE image during the outburst taken on 14 April 2018, showing both HD 92063 and V906 Car.



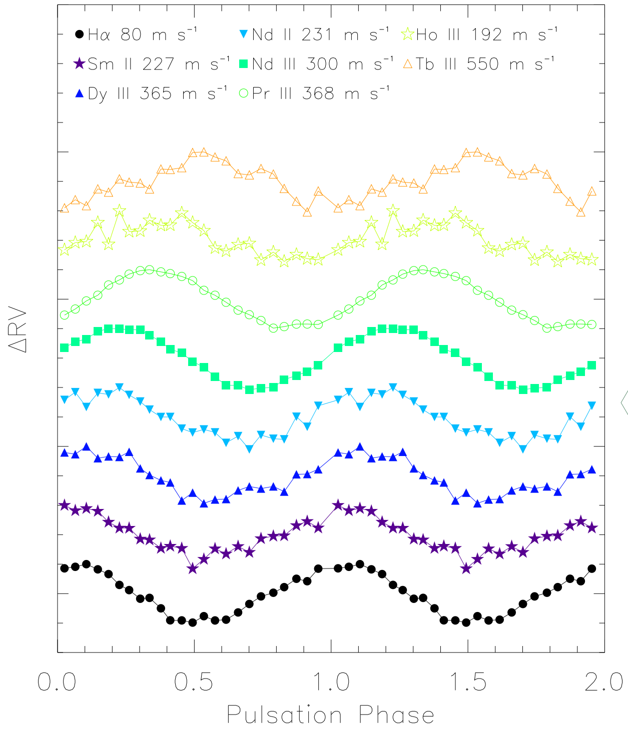
High-resolution optical spectroscopy of nova V906 Car showing several spectral features, highlighting the presence of multiple flows characterized by different velocities. The high cadence data provided by multiple facilities, including SALT, were critical to track the evolution of the system during the first weeks of the eruption.

Aydi, E., et al., 2020/04, Nat. Astron. 4, 776: Direct evidence for shock-powered optical emission in a nova

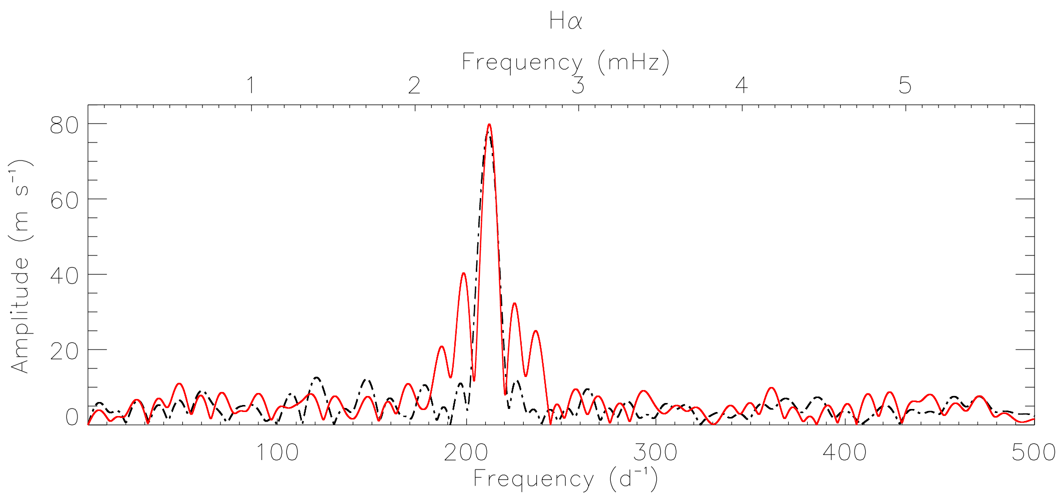
SALT HRS capabilities for time-resolved pulsation analysis: A test with the roAp star α Cir

Daniel Holdsworth (UCLan) and Emily Brunsden (U of York) have tested SALT HRS's ability to detect short-period pulsations in the rapidly oscillating Ap stars. These roAp stars, discovered at SAAO in the late 1970s, host pulsations with periods between 4 and 24 minutes and are often studied with photometric data. However, spectroscopy is a more powerful tool since, with high spectral and temporal resolution observations, spectroscopy is more sensitive to low pulsation amplitudes than photometry. Furthermore, with spectroscopy and oblique pulsation, it is possible to study how the pulsation propagates through the stellar atmosphere.

The authors used SALT/HRS in a previously unused mode to acquire high-resolution HS data of the brightest roAp star known, α Circini. Using the fastest readout mode and short exposures, they observed a cadence of just 30 s, enabling complete phase coverage of the pulsation mode. The authors benchmarked their results with data from the High Accuracy Radial Velocity Planet Searcher (HARPS) spectrograph, finding comparable noise characteristics between the two instruments. Furthermore, they were able to show the expected propagation of the pulsation through the stellar atmosphere by studying the variation of spectral lines at different atmospheric heights. This study shows that SALT/HRS is well suited to the detailed study of pulsating variable stars where high temporal and spectral resolution observations are needed.



Propagation of the pulsation from low in the stellar atmosphere (bottom) to high in the atmosphere (top). The amplitudes of the radial velocity curves have been normalized to the maximum of each element/ion, using the amplitudes stated at the top of the figure.



Amplitude spectrum of the radial velocity variations measured in the core of Hα. We detect the pulsation at a semi-amplitude of 80 m/s. The red line denotes the SALT/HRS results, while the black dashed line is the HARPS result.

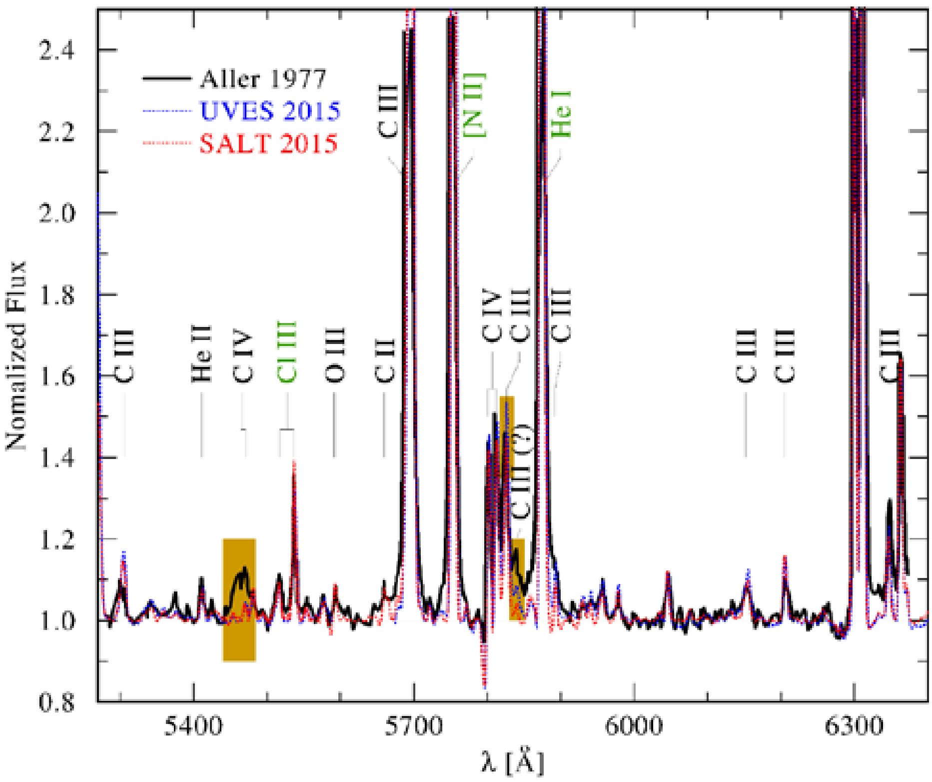
Holdsworth, D.L. and Brunsden, E., 2020/09, PASP 132, 105001: SALT HRS Capabilities for Time-Resolved Pulsation Analysis: A Test with the roAp Star α Circini

A late thermal pulse in a massive post-AGB star?

SwSt 1 (PN G001.5-06.7) is a bright and compact planetary nebula containing a late [WC]-type central star. Previous studies suggested that the nebular and stellar lines are slowly changing with time. Marcin Hajduk, from the University of Warmia and Mazury in Poland, and his colleagues decided to use archival observations between 1976 and 1997 together with new spectroscopic observations obtained in 2015 using the VLT/UVES and SALT/HRS instruments.

Comparing the measurements of the flux ratios from the different epochs, a decrease in the [OIII] 5007 Å/ Hβ flux ratio and the helium lines is visible. These changes are caused by a decrease in the temperature of the central star. In addition, the authors noticed a weakening of the C IV 5470 Å line and a strengthening of the CII 7231 and 7236 Å stellar lines between 1977 and 2015. Modelling the stellar atmosphere using Potsdam Wolf-Rayet (PoWR) codes, they find that the stellar temperature dropped from 42.0 kK around 1976 to about 40.5 kK in 1993. No significant changes were detected between 1993 and 2015, implying that the stellar temperature remained constant or had reached a minimum and is starting to rise again. This suggests that the star has completed a loop in the HR diagram, due to re-activation of the He shell burning, but without reaching the red giant domain.

The authors conclude that the temperature drop of the central star SwSt 1 was most likely driven by the activation of the helium shell due to the late helium outburst. It is likely that the star experienced a very late thermal pulse. In such a case, the AGB star would have to become a white dwarf and then return to the AGB region in just 190 years. There is no evidence that the observed changes are influenced by binary evolution. The comparison of the collected spectra did not show any variation in radial velocities.



Comparison of the spectra of the central star SwSt 1 made in 2015 and 1977.
Orange areas mark places in the spectrum where changes are visible.

Hajduk, M., et al., 2020/10, MNRAS 498, 1205: The cooling-down central star of the planetary nebula SwSt 1: a late thermal pulse in a massive post-AGB star?

Accreting pulsar caught in the act of 'powering up'

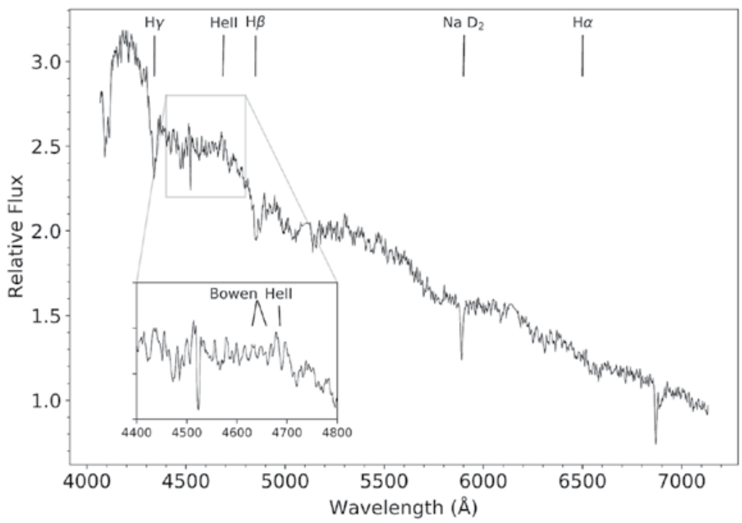
Observations across a range of wavelengths from the optical to X-rays have captured in detail – for the first time – the powering up of the outburst from an accreting neutron star. The physics behind what triggers such outbursts had eluded physicists for decades, partly because there are very few comprehensive observations of the phenomenon.

PhD student Adelle Goodwin from Monash University in Australia, together with an international team, used seven telescopes to observe the event: The Neil Gehrels Swift X-ray Observatory, the Neutron Star Interior Composition Explorer (NICER) on the International Space Station, the ground-based Las Cumbres Observatory network of telescopes and SALT (under the SALT Transient programme led by David Buckley from SAAO). This is the first time such an event has been observed in such detail at multiple wavelengths.

The observations of the low mass X-ray binary SAX J1808.4–3658 showed a continuing increase in the optical I-band from 12 days before the first X-ray detection with Swift/XRT and NICER on 6 August. The team found a 4-day optical to X-ray rise delay, and a 2-day UV to X-ray delay at the onset of the outburst. The optical spectra obtained with SALT/RSS during August 2019 proved crucial in demonstrating the powering-up: The first two observations on 2/3 August showed the object was very faint, while the third observation on 6 August showed it clearly in outburst.

The observational evidence supports the theory that the outburst is triggered by ionisation of hydrogen in the disc. The authors interpret the eight days of optical activity prior to the commencement of the outburst to be due to either increased mass transfer from the companion star, geometric effects in the outer accretion disc, or fluctuations in the pulsar radiation pressure, causing changes in the irradiation of the companion star, and perhaps the inner disc radius. They deduce that the viscous timescale of the disc in SAX J1808.4–3658 is approximately four days, consistent with the optical to X-ray rise delay observed. This is coincident with the time taken for the truncated disc to fill in to the surface of the neutron star, releasing UV and X-ray emission. Detailed modelling of the disc in SAX J1808.4–3658 is required to conclusively determine if this source exhibits inside-out or outside-in type outbursts.

Accretion discs are usually made of hydrogen, but this particular object has a disc that is made up of 50% helium, more helium than most discs. The scientists think that this excess helium may be slowing down the heating of the disc because helium burns at a higher temperature, causing the longer delay in the onset of the outburst (most theories suggest a 2- to 3-day delay).



SALT summed (2400 s) optical spectrum of SAX J1808.4–3658 taken on 6 August 2019 (MJD 58701). There are clear Balmer absorption features and weak HeII emission present.

Goodwin, A.J., et al., 202011, MNRAS 498, 3429: Enhanced optical activity 12 d before X-ray activity, and a 4 d X-ray delay during outburst rise, in a low-mass X-ray binary

SCIENCE HIGHLIGHTS

ongoing research

Other 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 example of these.

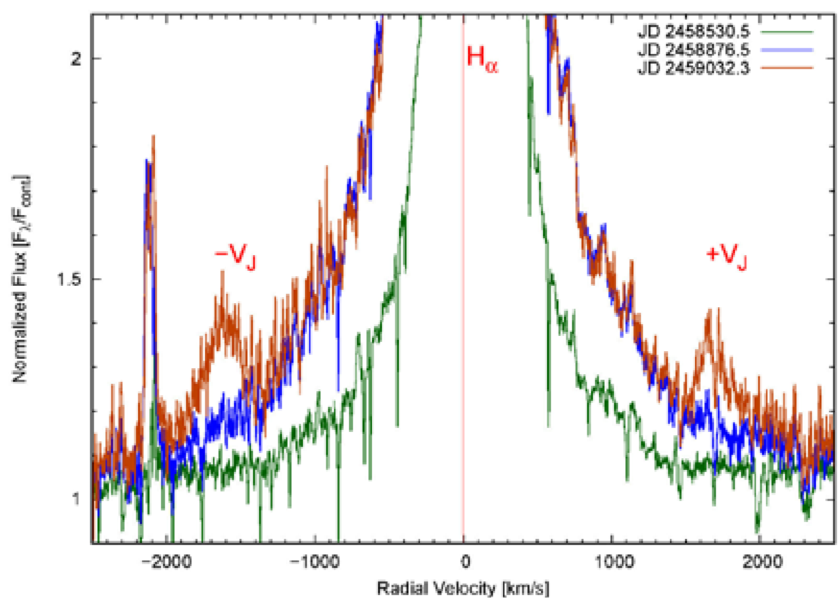
SALT detects jets in the outbursting symbiotic binary St 2-22

St 2-22 (PN Sa 3-22) is a poorly-studied classical symbiotic binary composed of an M4-type red giant and a hot accreting white dwarf. It is one of a handful of symbiotic systems (SySt) known to produce high-velocity (a few 10^3 km/s) collimated jets during their outbursts. However, so far only one outburst was noticed with only two spectra taken, and there are many issues to be properly addressed.

Cezary Gałan and Joanna Mikołajewska from Nicolaus Copernicus Astronomical Center of Polish Academy of Sciences have included this very interesting, but until now neglected, system in their ongoing systematic monitoring of selected Galactic SySt with SALT/HRS. Their programme aims at investigating their evolutionary status and past mass transfer, by chemical abundance analysis, and deriving orbital characteristics, by long-term monitoring of radial velocity changes.

In January 2019, St 2-22 showed a sudden steep brightening (by V~2 mag in ≲10 days) indicating a new active (outburst) phase that is still ongoing. The outburst behaviour of St 2-22 is very interesting and deserves careful investigation. Whereas the previous 2005 outburst was relatively short (it lasted for ≲200 days), the present one is much longer, and its amplitude, V~2.5 mag is larger than in 2005. The team has so far collected seven spectra with HRS in medium resolution (R~40,000) that cover the maximum and the standstill following the early decline reasonably well. In addition, a few low-resolution (R ~2000–4000) spectra were obtained with the 1.9-m Radcliffe telescope at SAAO with the SpUpNIC spectrograph.

The outburst spectra are characterised by strong H I, He I and low ionisation lines, initially mostly in absorption, but as the outburst continues an increasing emission component is observed which completely fills up the initial absorption in the most recent spectra. The most remarkable change, however, was observed in July 2020 — the appearance of two emission components at V_J ~ ±1630 km/s on the Hα emission wings that presumably originate in jets (see figure). The observations will be continued until the system returns to quiescence.



The evolution of Hα line profile in HRS spectra of St 2-22. Emission components from jets on the wings of Hα emission at velocity VJ ~±1630 km/s are clearly visible in the spectrum acquired on 1 July 2020 (JD 2459032.3).

Gałan C. & Mikołajewska J.

SCIENCE HIGHLIGHTS

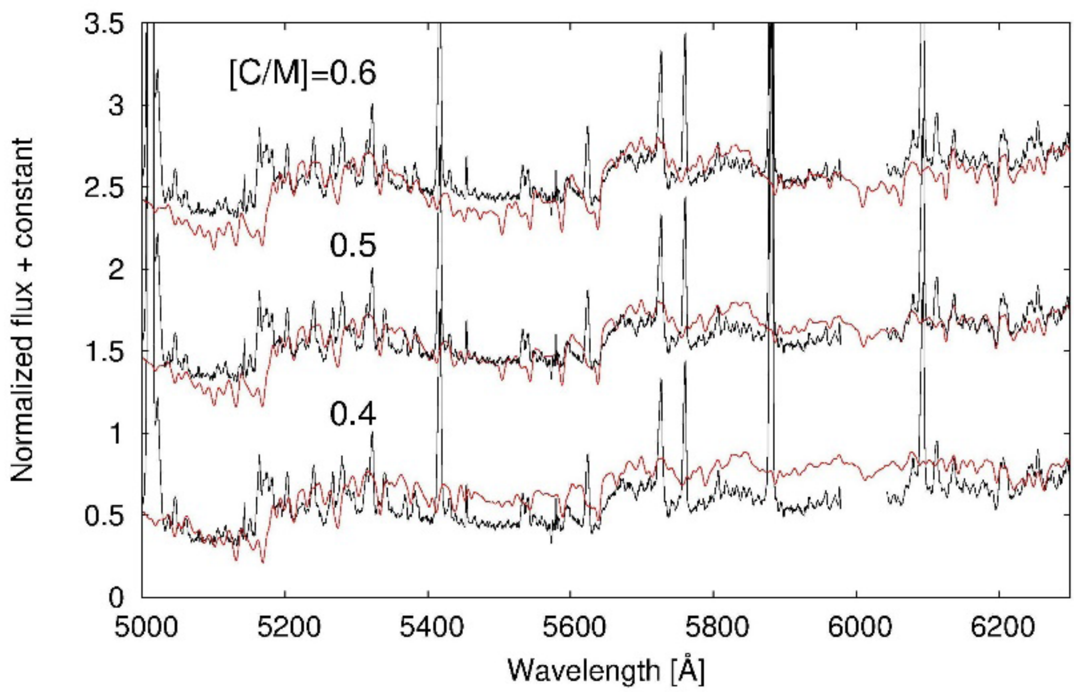
student projects

SALT discovers the first classical nova with a C-rich donor

Krystian Iłkiewicz from the Nicolaus Copernicus Astronomical Center of Polish Academy of Sciences (supervisor Joanna Mikołajewska) was awarded his PhD in February 2020. In his thesis, "Studying population of accreting white dwarf", SALT/RSS spectra were used to study two symbiotic stars (long-period interacting binaries in which a hot white dwarf accretes material from an evolved red giant) in the Magellanic Clouds.

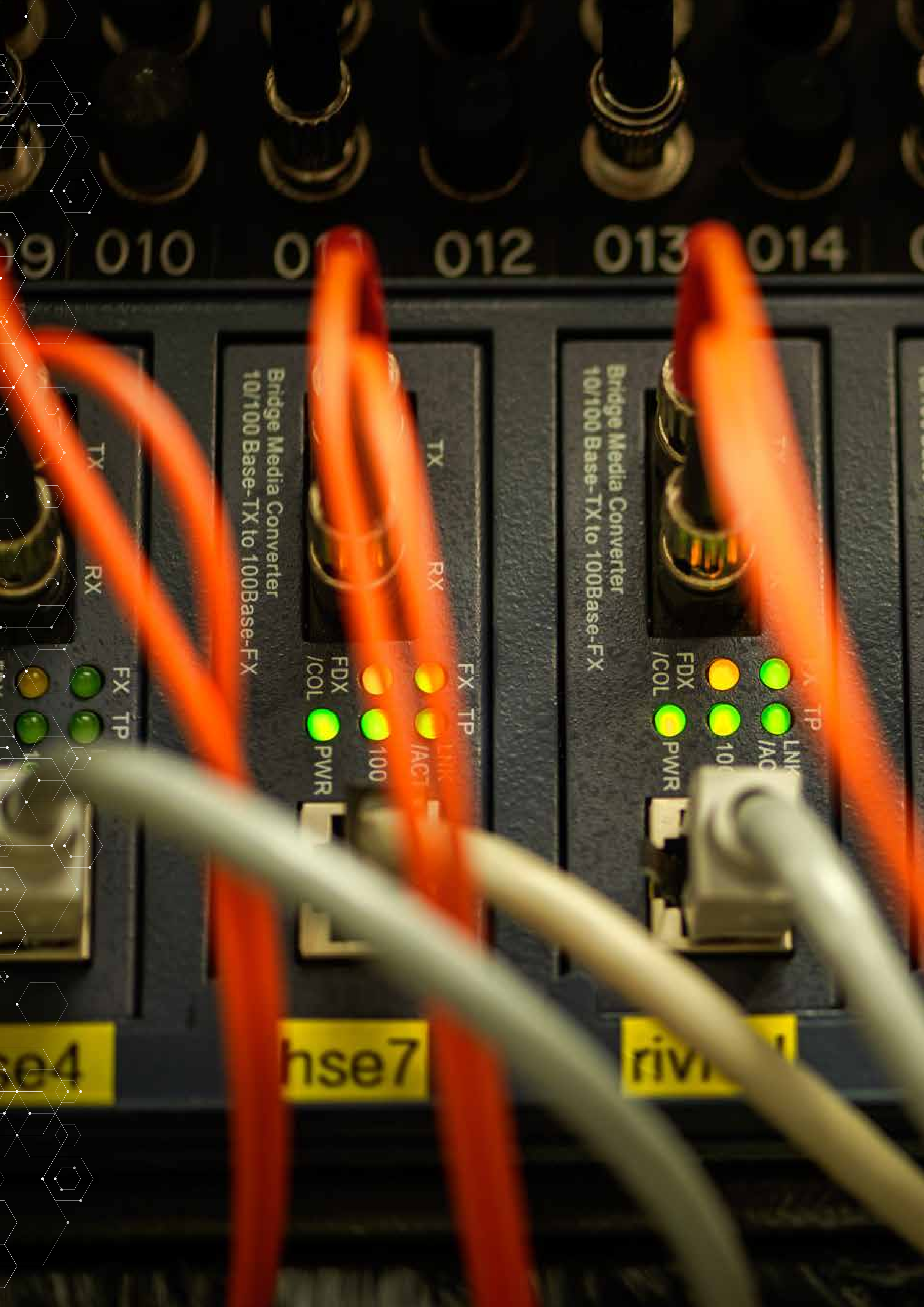
LMC S154 is a symbiotic star that has been suspected to have undergone a classical nova outburst in the past. With the help of the SALT spectrum, Iłkiewicz demonstrated that LMC S154 is indeed a symbiotic nova, making it the first symbiotic nova discovered in the Magellanic Clouds. The SALT spectrum was particularly useful in calculating the red giant chemical composition, showing that LMC S154 is the first classical nova with a C-rich donor ever discovered. Since the outburst properties of LMC S154 appear to differ significantly from other symbiotic novae, this system is an interesting case for the study of classical nova outbursts.

SMP SMC 88 was originally classified as a planetary nebula. SALT/RSS spectra were used to identify Raman scattered O VI emission lines (so far observed only in symbiotic stars) and to detect for the first time spectral features of a K-type giant in SMP SMC 88. Detailed analysis of all available data allowed Iłkiewicz to unambiguously classify SMP SMC 88 as a planetary nebula with a symbiotic binary as its central star. Such objects are among the rarest known classes of central stars of planetary nebulae, with only two other objects previously known.



Fit of synthetic spectra (red lines) to the SALT/RSS spectrum of LMC S154 (black lines).

Krystian Iłkiewicz, Nicolaus Copernicus Astronomical Center, Polish Academy of Sciences, Ph.D., 2020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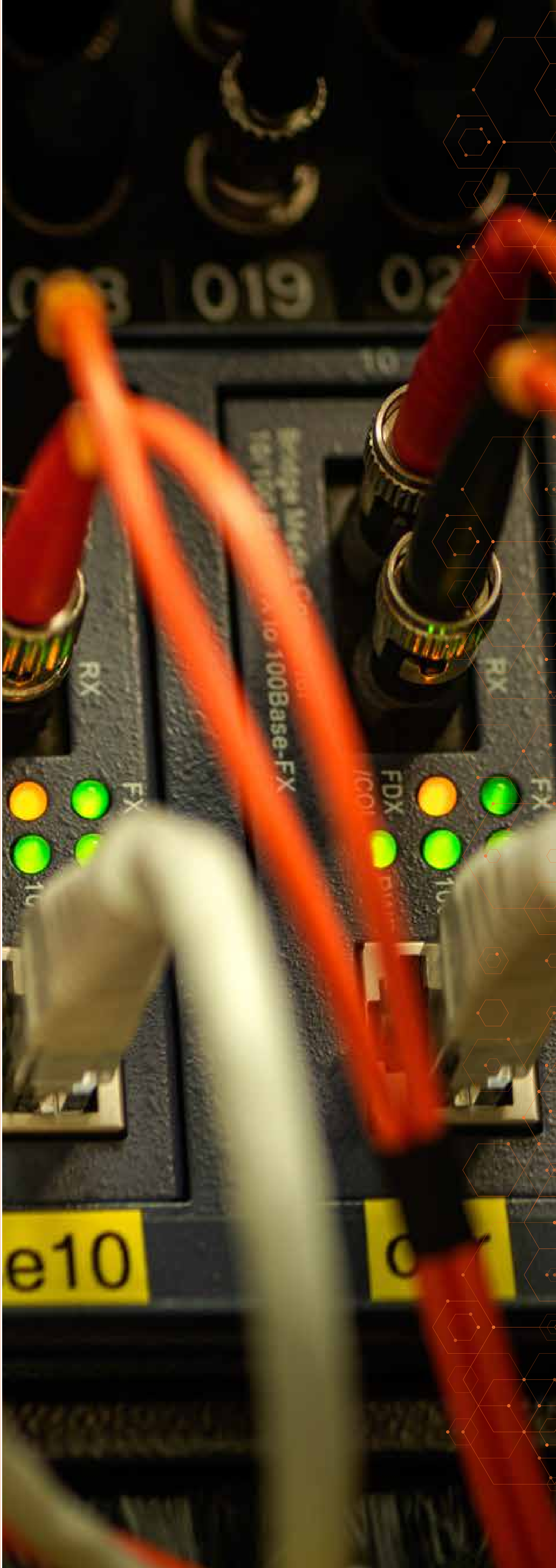
OPERATIONS



OPERATIONS

astronomy
operations

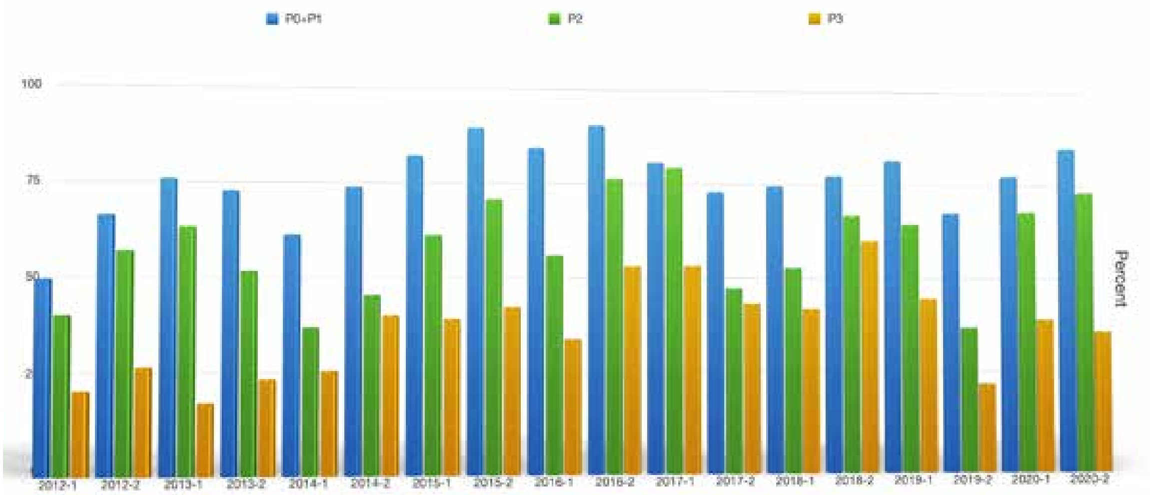
SALT Operations has undergone significant changes during 2020, following the unwelcome arrival of the COVID-19 pandemic. South Africa went into lockdown from midnight on 26/27 March 2020, halting all operations. We realised the virus was likely to be around for a long time, so we had to re-think our operation modes, with the result that, soon after the relaxing of the lockdown, by 8 May, we had successfully achieved remote operations from our homes. This was not as simple a change as it may sound, as we had to perform a risk analysis, identify critical gaps and reallocate tasks and resources to make it work, but we are proud to have achieved this in a relatively short period of time. To date, SALT continues to be operated remotely.

Semester statistics

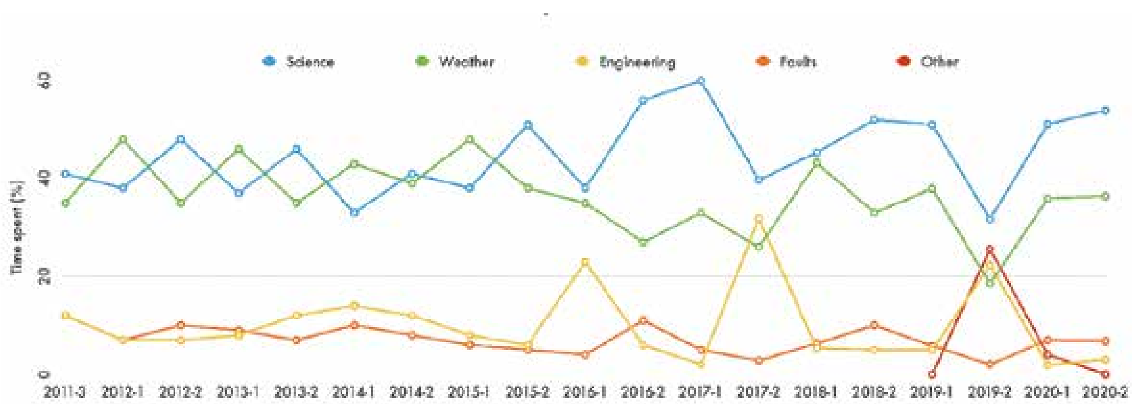
Our completion levels suffered during the COVID-19 nationwide lockdown that started on 27 March and which prevented any observations for the remainder of the 2019-2 semester, though this affected mainly P2 and P3 proposals. Semester 2020-1 started remotely only a few days late (on 8 May instead of 1 May) and our completion statistics were gratifyingly similar to previous semesters.

The impact of COVID-19 shows prominently in our time usage per semester. We added a category "other" (in red) to indicate the time lost due to the lockdown and/or network problems (affecting remote observations) that have now become our main source of technical downtime. They are receiving attention, with a new backup link being investigated and a future upgrade expected in late 2021.

In terms of instrument usage, RSS continues to be our main workhorse instrument, mainly requested during our very best conditions (dark, clear, good seeing nights). HRS, on the other hand, is our main instrument for bright nights and worse seeing conditions.



Completeness per priority in percent

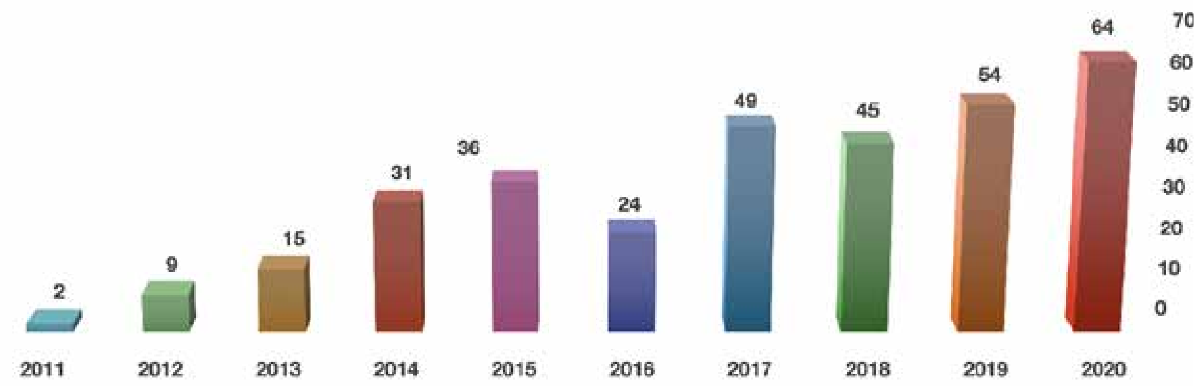


SALT time usage per semester

Publication statistics

SALT is continuing on the publication trend expected for a telescope of its age and size, and broke another record for SALT refereed publications with 64 papers in 2020 (including one instrument paper). This is 10 more than last year and brings us to 329 papers since the beginning of full science operations in 2011. The 2020 publication topics are equally divided between Galactic astronomy papers (N = 30) and extragalactic astronomy (N = 31), the latter with a strong component from the supernovae (N = 8) and gravitational wave (N = 3) communities. A further paper was on solar system objects and another one on exoplanet sciences.

As with the observations, RSS continues to be our main source of publications, though HRS contributions have been steadily increasing over the last few years. SALTICAM's lack of guidance and difficulty with maintaining focus has made it less attractive to our users. The pointing and focus of the telescope have been receiving attention and have now improved significantly, so we expect an increase in SALTICAM publications in the next couple of years.



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

User support

A new primary reduction pipeline was launched in 2020. It has been written fully in python 3 and supported by our dedicated pipeline SALT Astronomer, Enrico Kotze. This new pipeline has led to extra information being sent to PIs, such as the guider information during the observation, whether the data were accepted or rejected, and various other upgrades.

The year also saw the launch of the new SALT Data Archive (SDA) on 10 July 2020 (https://ssda.saao.ac.za/), allowing anonymous and authenticated user downloads of SALT public data. When launched, the SDA contained data from 1340 proposals from 2011 onwards, of which 926 were already public at that time. SALT data becomes publicly available in the SDA after the following periods, counting from the end of the last semester that datasets were taken for the relevant proposal:

- Science proposals: 36 months, or 24 months if South Africa has allocated time
- Director's Discretionary Time (DDT) proposals: 6 months
- Gravitational-wave proposals (GWP): 0 months, data only available to SALT partners
- Commissioning proposals: 36 months
- Performance verification proposals: 12 months

Science proposals with no South African time allocation can extend their proprietary period as needed. For all other proposals, the PI must send an extension request per proposal, together with a justification, which will be processed and granted if deemed reasonable. Both can be done from the relevant proposal's page in the Web Manager.

Personnel

Dr Lee Townsend joined our team as a new SALT Astronomer in February 2020, filling the vacancy from Dr Brent Miszalski. Lee became the instrument scientist for RSS and is heavily involved with the project developing the new Red Arm for RSS Dual.

Dr Marissa Kotze resigned in July 2020 from her SALT Astronomer position, and her position remained vacant for the remainder of the year.

Mr Sifiso Myeza was head-hunted and resigned from his Software Developer position in August 2020, and his position also remained vacant for the remainder of the year.

Mr Lonwabo Zaula's contract as a SALT intern was extended by the Department of Science and Innovation for an extra year.

Dr Anja Schröder's contract as PR officer ended in March 2020, with the printed SALT Annual Report 2019 just being delivered before South Africa's lockdown started on 27 March.

OPERATIONS

technical operations

For the semesters 2019-2 and 2020-1, the telescope's technical downtime increased slightly to 4.1%. Many problems were sorted out during the five-week 2020 **maintenance shutdown** (10 February to 16 March) including important tasks that will affect long-term reliability and data quality. The major tasks were the cleaning of one of spherical aberration corrector mirrors, installation of the new controllers for the mirror Segment Positioning System (SPS), measuring the RSS frame for the new red channel, reworking the RSS waveplate mechanism to improve its reliability and confirming the optical alignment and collimation of the RSS. Along with these major tasks, a host of minor maintenance tasks (such as cleaning the SALTICAM, RSS and payload optics, as well as the ADC) were also completed.

COVID-19: On 27 March 2020, South Africa, like many other countries at around that time, entered a lockdown period due to the novel coronavirus SARS-CoV-2. SAAO and SALT decided a week before the time to shut down operations. During the lockdown period, only standby personnel were allowed at the telescope to perform daily checks. After doing risk analysis and mitigation, we were able to ready SALT for remote observations from 8 May 2020. This meant that instead of having a SALT Operator and a SALT Astronomer at the telescope for nighttime operations, they were able to control SALT from the comfort of their home or the remote observing room in Cape Town. However, this came with new challenges, one being the availability and reliability of the internet connection on our backbone, as well as from the operator and astronomer's remote stations. There were frequent problems due to theft and vandalism of the backbone-fibre link between Cape Town and Sutherland, particularly towards the end of 2020. The backup link that we use unfortunately also runs on this backbone and so an alternative solution based on the cellular telephone network is being procured for testing as a temporary solution. An upgraded fibre backbone is in the works, as well as installing a new fibre link on an alternate route. Together this will give us two 10GB/s links, as opposed to our current single 1GB/s link.

With critical maintenance staff that only returned to work on 29 May 2020, the **primary mirror** coating schedule lagged. With the assistance of other staff washing mirrors while the dedicated mirror team replaced mirrors, the rate of mirror coating safely increased to six mirror segments a week, bringing us back to our scheduled year-to-date target.

Many SALT systems are starting to age or become obsolete. **Asset renewal projects** where computers together with the controller cards are old and obsolete will be or are in the process of being replaced with modern controllers. We are also looking at turnkey solutions where possible. This will ensure better support, less downtime and, in the case of a turnkey solution, less use of the already overburdened staff's time to help speed up the replacement of these subsystems. The SPS was successfully upgraded in March 2020 and has been operating reliably ever since. The Mirror Coating plant and SDC (Structure and Dome Controller) is currently receiving attention.

Many staff members are also involved in **high priority projects** such as the NIR, RSS Dual (aka the MaxE project) and the reprioritised "RSS Big 5". The latter was identified in the September 2020 Board Executive Committee meeting and consists of the RSS doublet and RSS triplet lens replacements, the manufacturing of a new 700 l/mm grating, new long-slit holders and slitmask letterbox, as well as the RSS detector upgrade. The RSS guider pre-positioning project also received high priority attention and has made good progress since then. This will improve nighttime efficiency by decreasing the acquisition time for RSS targets. The telescope pointing and focus model has also received high priority attention with some configuration improvements already implemented in the model. The NIR is now receiving full attention between the Wisconsin and South African teams and has made great progress in 2020. The instrument is due to ship from Wisconsin in December 2021, after which unpacking, assembly, integration, testing and commissioning will begin. The ADC Optics and Opto-Mechanical integration was outsourced to Officina Stellare in Italy and delivery is expected in October 2021.

With the drastically increasing costs of electricity, SALT had decided to install a 40 KVA **solar power plant** which was completed in December 2020. The new system has full reporting on usage and cost savings based on the programmed electricity tariffs.

Personnel

SALT TechOps appointed two new members to the team in 2020:

- Mr Bryne Chipembe (Software Engineer – Sutherland)

- Mr Sunnyboy Kabini (Software Engineer – Cape Town)

New staff have made good progress on many levels to alleviate the burdens on existing operational staff that are working on the larger projects such as the RSS Dual and the NIR. An NRF-wide COVID-19 related moratorium on jobs unfortunately prevented us from recruiting more critical skills during the rest of the year.

Attention is also given to upskilling staff where needed, including identifying courses or training required in the future, especially in the field of optics.

Health and safety

Safety protocols were put in place to prevent the spread of COVID-19 in the workplace, while many staff worked remotely where possible. During 2020, we can gladly say that no SALT staff had contracted the virus. Employee wellbeing is always important, and we welcome the services of Incon Health which were appointed by the NRF to assist all staff and their direct families with any challenges they may be facing. This is especially important during the current pandemic.

A new automated fire sprinkler system was installed in the paint store, as well as a hose reel system in and around the SALT telescope. This provided the much needed mini-team building event while receiving training on the use of the system. The onsite ambulance remains in good shape, with all medical equipment now replaced after the Incon Health representative identified a few expired items.

All staff remain in good health with no serious injuries during this reporting period.

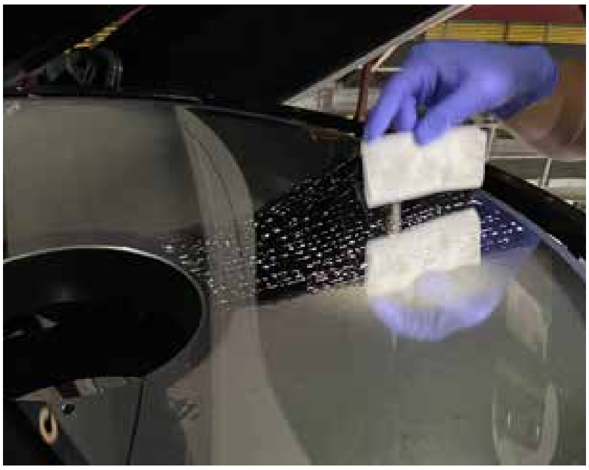
OPERATIONS

instrument news

Cleaning the Spherical Aberration Corrector

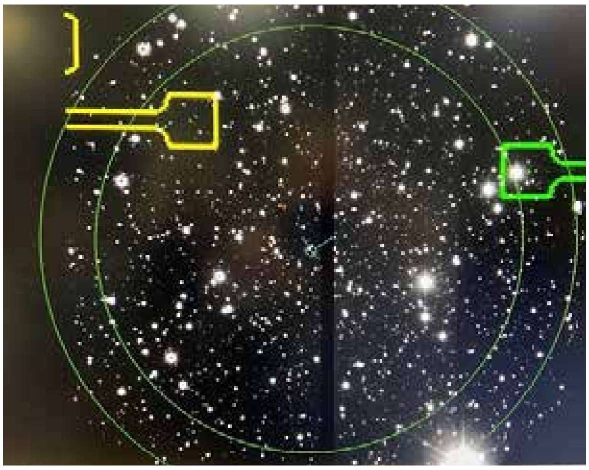
The main SAC intervention during the 2020 shutdown was to detach, wash and replace the upward-facing mirror at the bottom of the corrector (M3), while working on a small platform suspended from the tracker bridge. This entirely new procedure went very smoothly and yielded a 10–15% increase in reflectivity and a dramatic (~50%) reduction in scattering, as measured with our new 7-wavelength hand-held reflectometer. The M3 coating is still in extremely good condition.

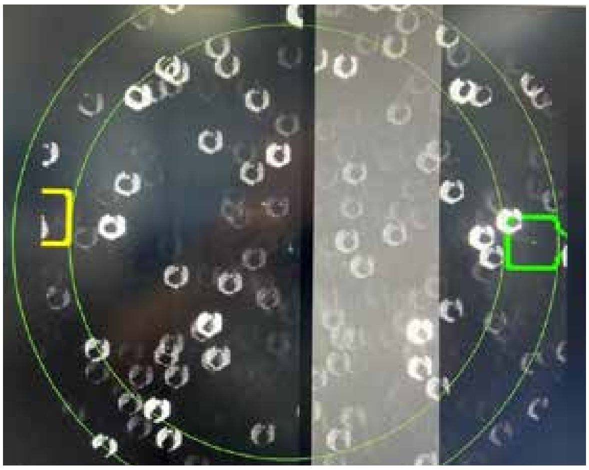
The removal of the M3 mirror and the rotating structure in the payload provided access to inspect the other SAC mirrors during the shutdown. It was possible to make reflectometer measurements on the large, downward facing M2. M4 and M5 are both highly curved and thus not amenable to such measurements. We were alarmed to find that M2's multi-layer coating has spontaneously degraded since it was last seen about a decade ago. Illuminating the mirror produces a halo of bright scattered light, regardless of where/how the light is directed at the surface, so it seems that the deeper layers have deteriorated for some reason. Fortunately, the peak reflectivity appears to be >90%, the scattering is less than that of a dusty mirror and we checked that the coating is not delaminating, but this surface will need to be re-coated to restore its performance. M4 is still in excellent condition, but the top upward-facing mirror (M5) is significantly worse off than when it was cleaned (in situ) in mid-2016. M5 is quite dusty again and the old glycol spots from a major payload leak in 2012 are now showing signs of the coating failing and beginning to delaminate in those areas. The M5 surface is now considered too vulnerable to clean, so re-coating the mirror is the only option for restoring it. Although M4 can easily and safely be removed to afford access to the optical surface of M5, extracting M5 for re-coating will require more drastic interventions, best done with the SAC on the ground. A comprehensive SAC maintenance plan needs to be formulated and executed in the future.



Cleaning the M3 mirror.

Reflectivity and scattering measurements with the CT-7.





In focus (left) and out of focus (right) images, taken after the re-installation of M3, show no sign of coma, confirming that the mirror went back exactly as intended, without degrading SALT's image quality.

A laser frequency comb the HRS-HS mode

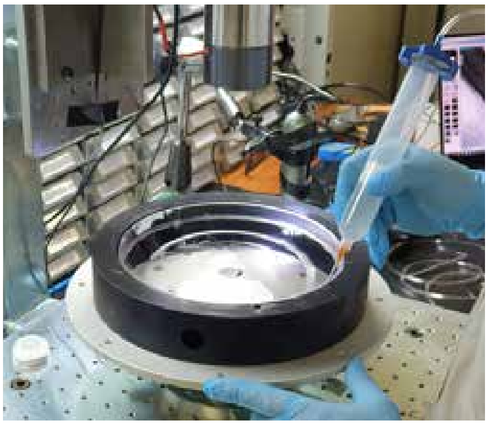
Work has been underway for a while to investigate the suitability of the High-Resolution Spectrograph (HRS) for pursuing exoplanet science. The spectrograph's high-stability (HS) mode has two specialised wavelength calibration options for precision radial velocity (PRV) measurements. These are the iodine cell (a gas absorption cell that superimposes a well-defined series of absorption lines onto the stellar spectrum) and the "simultaneous Thorium Argon" (ThAr) channel, whereby arc light is injected into the calibration fibre at the same time that starlight travels along the target fibre.

The iodine cell is a workable option for the brightest targets ($V < 8^{m}$), but unfortunately, it cannot be considered competitive for exoplanet science, due to the throughput loss caused by the spectrograph's dichroic split falling in the middle of the iodine absorption spectrum. Thus, we have been investigating the viability of the HS mode's ThAr channel, particularly whether it will make sense to acquire a laser frequency comb (LFC) to support this approach. The key issue to consider is the intrinsic stability of the instrument, since the simultaneous ThAr or LFC relies on injecting calibration light down a different fibre to that used for the target. If the instrument itself is not stable enough, that simultaneous calibration will not be representative of what the target fibre experiences and so there would be no point acquiring a highly specialised precision calibrator. Stability tests measuring velocity shifts between the two HS fibres indicate that the system is indeed stable enough to justify the acquisition of an LFC. A quote for a comb that would be suitable for HRS has therefore been requested from the Ultrafast Optics group at Heriot-Watt University (whom we worked with in 2016 to test an experimental LFC on the HRS).

Components of the experimental laser frequency comb tested at SALT in 2016.

Short-term projects: The RSS "Big 5"

A decision was taken at the September Board Executive Committee meeting that the SALT team would prioritise a set of key initiatives to improve the performance of the RSS in the short term. This compound project was dubbed the "RSS Big 5", consisting of the following elements: new long-slits with the focal plane letterbox where the slit in use gets inserted into, a new 700 l/mm grating, a new collimator doublet, a new collimator triplet and a new detector package. Most of these were already in progress at the time, but the point was to prioritise these above the other major projects (such as MaxE and the local preparations to accommodate the NIR) to get these out of the way and thereby reduce the pressure on overloaded resources. The aim is to complete the first four of these five projects relatively quickly for installation during a single shutdown in 2021. The new detector package has a longer timeline and is only expected to be installed at the end of 2022.



Injection of the Sylgard bonding agent during the integration of the RSS collimator doublet's fused silica element.

Other RSS projects

The project to refurbish and upgrade the low and medium resolution **Fabry–Pérot** etalons is in progress. The vendor responsible for the new etalon coatings took longer than anticipated to commission their new coating plant, and COVID-19 added to the delays. But the order for the coating development (to be done on small substrates before eventually progressing to the actual etalons) was placed in July. A new postdoc has been recruited to support the recommissioning of this mode, including a comprehensive overhaul of the SALT Fabry–Pérot software tools.

A phased approach was adopted for the important **RSS guider pre-positioning** project, which will see the two guide probes for the RSS being pre-positioned to pick up the required guide stars ahead of each acquisition. The basic functionality is now in place and in regular use at the telescope, with refinements being made to improve the performance. Having the software lead for this project regularly joining the observers in the early evenings led to detailed real-time discussions and the incorporation of valuable feedback from the SALT Operators in particular. We look forward to the reduction in acquisition times that this new capability will deliver.

Another exciting addition to the RSS will introduce a powerful new capability in the form of a compact, deployable integral field unit (IFU). This is referred to as a **slit-mask IFU**, since the short lengths of fibre and array of small fold prisms will be housed within a modified version of a RSS long-slit mask. Excellent progress has been made on this project since the new fibre lab at the SAAO in Cape Town was completed and the associated postdoc arrived in South Africa. The small fold prisms have been ordered and work is being done to get the hardware manufactured in the SAAO mechanical workshop. Fibre glueing and polishing jigs are also being developed and fibre cross-talk has been evaluated to guide the spacing requirements for the fibres at the pseudo-slit. The firm goal is to have the first two slit-mask IFUs on the telescope within the coming year.

NIR: Progress on the integral field spectrograph

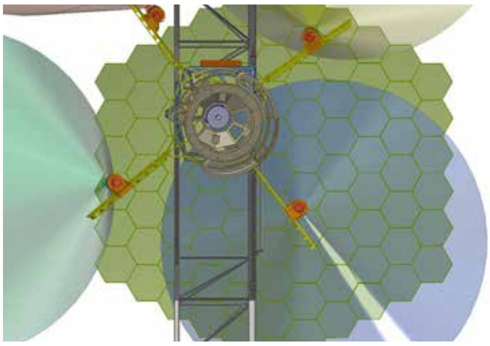
While the development of the fibre-fed near-infrared spectrograph (dubbed NIR) is proceeding apace at the University of Wisconsin (UW), there are also a number of tasks to prepare the telescope to receive the new instrument. These include arrangements to route the NIR fibre cable, ensuring that SALT can provide the facilities needed to support NIR and the addition of specific hardware and software infrastructure. A contract for producing and integrating the large fused silica prisms for the new atmospheric dispersion compensator (ADC) was signed with an Italian company. Final integration of the two prisms into the ADC's electro-mechanical housing will be done by SALT staff before this new assembly can be installed and commissioned. Adapting the SALT calibration system (calsys) to accommodate the NIR's needs is proving challenging due to the very wide wavelength range that it will need to operate over. Since suitable transmissive materials are not available, options for an all-reflective calsys design will be explored. Work is progressing to test and characterise the types of offsets that can be made with the fibre instrument feed (FIF) to support the NIR use cases, and modifications to the separation stage of the FIF will be needed to accommodate the NIR IFU head and sky bundles. The UW and SALT software teams are also working closely to sort out the architecture and distribution of labour for each of the different types of software relating to NIR. These include instrument control, detector control, science software (observation planning tools, quick-look and data reduction pipelines) and all of the relevant interfaces to the SALT software ecosystem. The new instrument and its large thermal enclosure are due to be shipped to South Africa at the end of 2021.

RSS Dual and MaxE

This project deals with the development of a new red optical channel for the RSS to support SALT's transient identification spectroscopy needs, a capability that we refer to as the RSS Dual mode. All of the present functionality of the RSS will be preserved and remain available to SALT users, but the Dual configuration will require the introduction of a dichroic beam-splitter. This needs to be interchangeably deployable in place of the current RSS fold mirror, to divide the spectral range around 630 nm. In this setup, the current RSS will serve as the Blue arm (operating from 360 – 630 nm) and the MaxE project will deliver the new Red arm (from 630 – 900 nm). This Dual-mode will then provide simultaneous wavelength coverage across most of the optical range, with resolving powers suitable for identifying the wide variety of transient objects that future facilities like the Vera-Rubin Observatory (LSST) and the Square Kilometre Array (SKA) will uncover in vast numbers. The RSS Dual conceptual design review was held at the end of January 2020 and work has been underway to respond to points raised in the review, and to evolve the various designs to be ready for the preliminary design review in late 2021.

Mini-Trackers

At the November 2019 SALT Board meeting in India, and at the request of the SALT Board, a proposal was presented to perform a study to determine the feasibility of designing and building a device called a "mini-tracker" (MT) for the telescope. By taking advantage of SALT's large uncorrected field of view, mini-trackers would enable the telescope to acquire and independently observe more than one astronomical object at a time, including objects widely separated from the SALT target under observation. These devices would be replicable, so that upon the successful demonstration of a prototype MT, more could be built and deployed on the telescope with minimal additional engineering design cost.



Schematic illustrating the deployment of four mini-trackers (MTs). The aperture of each MT is represented by a coloured cone and their patrol fields are defined by the yellow arms being able to sweep out an arc and the mini-corrector being able to travel along the arm.

The feasibility study mostly comprised mechanical and optical design efforts. The mechanical aspect focused on developing 1) a practical means of attaching the MT to the existing tracker, and 2) a deployment mechanism to position a mini-spherical aberration corrector (MSAC) within the primary mirror field of view. The optical effort centred on developing a variety of MSAC designs of different apertures. Preliminary estimates for budget and schedule were produced and a science case for the MTs was also developed.

The study concluded that mechanical solutions exist for the mini-trackers, and optical solutions for the MSAC are within reach. The project, therefore, appears to be sufficiently feasible to pursue through the concept design phase, though more work is needed to ensure that the science goals envisioned for the project match the better-understood capabilities of the MTs. The onset of the COVID-19 pandemic midway through the feasibility study meant that not all aspects of the study could be completed as planned. Work continued through the rest of the year and at the November SALT Board meeting the team presented a Statement of Work for the Project Definition phase to follow.

OPERATIONS

software
updates

Software projects finalised in 2020 include the SALT data archive and the SALT primary reductions pipeline. Work is ongoing to further develop data quality monitoring scripts and tools, as well as to update and improve the PIPT and the Web Manager. Our newest SALT Astronomer is also looking into refining the observing block scoring algorithm to help guide the way observations are dynamically prioritised in the queue. Our new team member Bryne Chipembe is based in Sutherland and will be working on BMS and SDC among other subsystems and projects.

Adapting to the pandemic

While the pandemic has not made a large impact on the daily work that we do, it has significantly changed how we do it. Since the nationwide lockdown was implemented, our team members have been working from home, and only coming into the office when absolutely necessary – mostly to interact with hardware on-site. With the office in Cape Town closed and travel within the country restricted, team members have been working from Cape Town, Sutherland, and Johannesburg. While turning around in your chair, walking down the corridor, or going to tea to ask a person a question is no longer possible, we have instituted a weekly online meeting to streamline working together from remote locations. These Zoom chats have been effective at keeping in touch with each other and increasing communication within the team.

A positive side effect of the pandemic is that it is now easier to support nighttime operations. The SA and SO are now working from a virtual Zoom room, instead of the SALT Control Room, greatly increasing the ease (and decreasing the financial cost) of communicating to both SA and SO directly, since one can now just join a Zoom call instead of phoning the control room directly and trying to talk to someone on the phone and in the background.

Internal projects

We have also completed an audit of software and machines that are part of regular operations. This has assisted us in maintaining our existing software as we strive to have two engineers familiar with the internals of each subsystem. As part of this, there has been significant cross-training between team members in recent months. In addition, the team has been continuing to train our newest members, Sunnyboy Kabini and Bryne Chipembe, in telescope operations and software design principles at SALT.

While we are certainly in interesting times, the software team has been working well together to adapt to the changing work environment as we continue to support and further develop the telescope system

The software side of the guider pre-positioning project

Automatic probe positioning of the telescope's guidance probes has been pushing ahead despite pressures from the development of RSS Dual (née MaxE), SALT operations, and of course the COVID-19 conundrum. Once completed, this will position the guide probes over the expected location of the guide stars as part of the telescope's point-to-target procedure. This will decrease the acquisition time, not only by pre-positioning the guide probes but also by reducing the need to nudge the science target into the slit.

The required changes to position the probes have been made to the Telescope Control System (TCS) and fine-pointing accuracy was verified with on-sky engineering tests in the early evenings. The deployment plan was to have guide probe pre-positioning operational for RSS as soon as is practical, followed by the HRS guide probe soon afterwards. Finally, the guide star selection script will connect to an on-site guide star database, allowing the pre-positioning system to continue to function even if internet access is not available.

Porting the HRS detector machines to Linux

The HRS detector machines were originally delivered as Windows systems. While completely adequate for the purpose and even presenting some scope for improvement, there had been various drawbacks. The use of any Windows computer is limited to the graphical interface. As a result, only one person can be working on the computer at any given time. Furthermore, the low-level CCD control logic used on the Windows system is essentially a black box. While the source code is available to us, we are dealing with unfamiliar software where we have little knowledge of the internal workings or design intent of the software. To address these various impediments, it was decided to port the detector systems to Linux, in particular since all other instruments are also on Linux. This would also give us more fine-grained control of the software environment.

The low-level CCD control on Windows was accomplished via the Astronomical Research Cameras (ARC) supplied application programming interface (API). While the same software is available for Linux, it was replaced by an in-house developed software library, written from scratch to accommodate the peculiarities of the various instruments in use at SALT. To link the LabVIEW control software to the new software library, a thin glue layer of software was written in C to act as a drop-in replacement to the ARC API software. In other words, it presented the same API as that presented by the intermediate C++ layer that was used to interface to the ARC API.

The LabVIEW software could then be moved from Windows to Linux requiring virtually no LabVIEW software modifications. This route was chosen to minimise the application software changes, thereby reducing the opportunity of introducing new software bugs during the porting process. In other words, any software defects that were uncovered could be directly blamed on the newly written C software, rather than first going through a process of determining whether the bug lies in the modified LabVIEW part or the newly written C part. It should be noted that the C software had been under part-time development for some years, and had reached a sufficient level of maturity before the HRS Linux port was started.

The initial port of the HRS Red detector was started in 2019. The Linux-based HRS Red detector went live at the end of Jan 2020. The Linux HRS Blue detector went live in mid-March 2020, just in time before the telescope shutdown.

One of the major issues we had hoped to address with the Linux port was intermittent readout failures that would cause one of the two detectors to fail to read out the image data at the end of an exposure. If this happened, the entire (up to one hour long) exposure would be lost. Unfortunately, the Linux port did not solve this issue. The port, however, gave us much increased knowledge about the detector control intent, and also allowed finely tuned logging to be inserted at the key points in the software — luxuries we did not have on the Windows system. This allowed us to track down the failure to the exact method that was used to indicate the end of exposure in the detector firmware. It appears that there was a race condition present in the firmware which would only present very infrequently, but with devastating consequences.

Addressing this race condition was done by sidestepping the logic that caused the problem entirely. This was accomplished by the addition of a specific command in the firmware to indicate the end of exposure, and to trigger the readout. Since adding this command, and modifying the detector control library to use it, we have not had a single readout fail. This fix was made at the start of May, just in time for the start of remote operations.

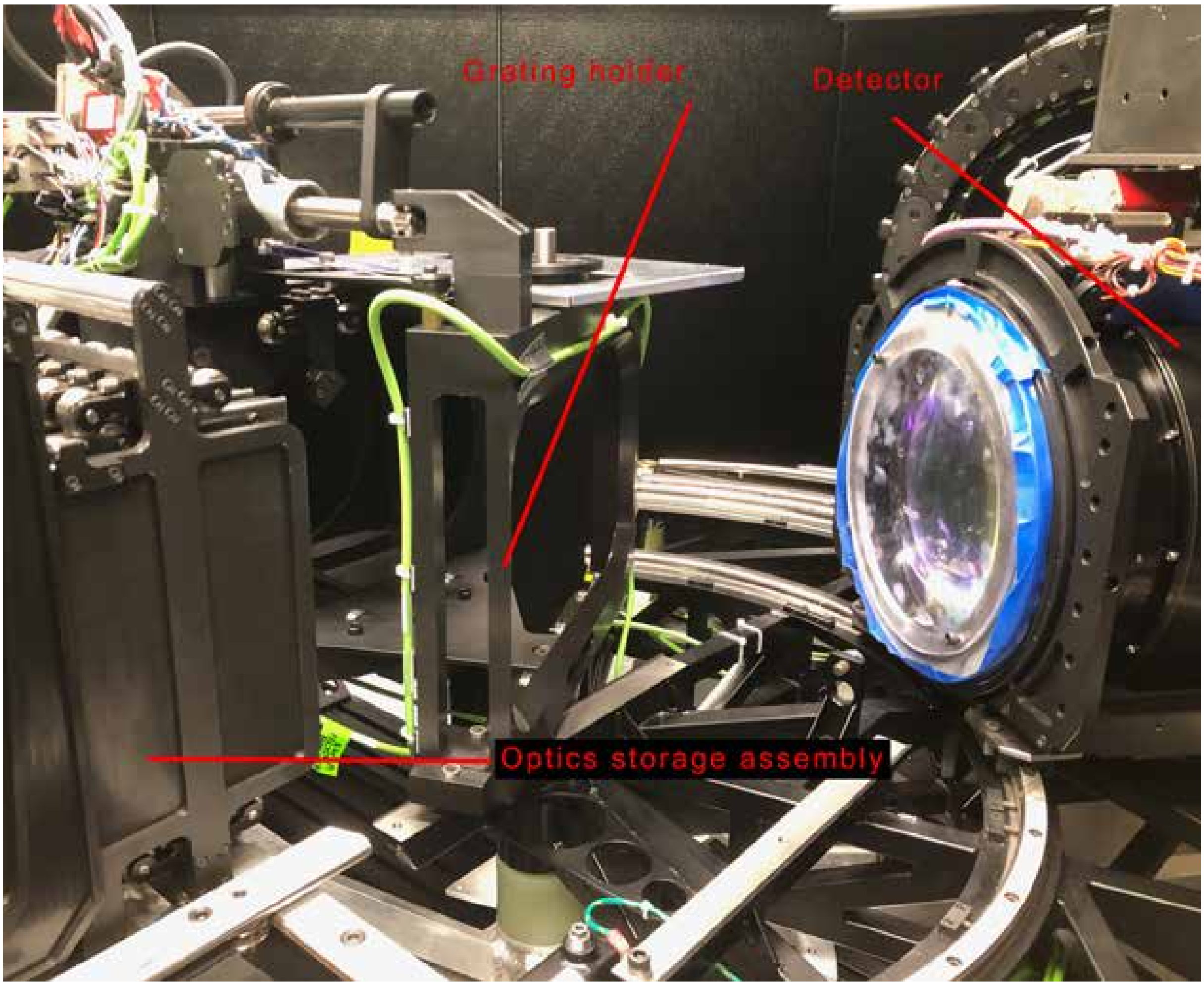
Structure and Dome Control upgrade

The Structure and Dome Control (SDC) system needs to be upgraded as part of the obsolescence project and to improve the usability, reliability, and maintainability of the subsystem controller. The development of the new SDC started with the requirements analysis, whereby use cases, the interface control document, and a draft software requirements document were generated. The software development was broken down into two modules: the SDC Main application, which is still under development, and the SDC Human Machine Interface (HMI) application. The development started with the HMI and this is now complete. The aim is to improve usability by focusing on the layout, ease of navigation, and ease of learning.

The framework being used for the SDC software has been used in the Building Management System (BMS) and Segment Positioning System (SPS) and it has proven to be reliable. The look-and-feel of the BMS and SPS user interfaces has been adopted for use in the SDC HMI. The goal is to have consistency across all SALT software by having a similar look and feel. Reviews were done to ensure consistency in SALT software development, compliance to coding standards, and for the team members to gain a better understanding of the SDC subsystem.

NIR development

Progress is being made on the software requirements for the NIR control software. These requirements are largely based on the information in the Operational Concept Definition document and also from working through a systems engineering approach based on the SARAO systems engineering process. This has allowed us to identify many of the features the control software and user interface will require. The University of Wisconsin team has made giant strides in getting the instrument hooked up and tested, to the extent that they were able to send SALT staff an impressive video showing the various mechanisms in action.



Assembled RSS-NIR camera lens (right) and optics (left) at the UW instrumentation lab.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OUTREACH & EDUCATION

OUTREACH & 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.

The year 2020 has been a difficult, tough, and challenging year due to the outbreak of the COVID-19 pandemic, which affected and severely limited the public outreach programmes. Despite all the challenges and limitations, we managed to successfully implement a number of programmes during the pre-COVID-19 period (January to March), continuing with online projects during the Level 5 and Level 4 stringent state lockdown and the more relaxed lockdown periods, Levels 3 to 1.

Pre-COVID-19: January – March 2020

A total of 2262 people were reached through a number of activities which included: learner workshops, school visits, exhibitions, teacher workshops, open nights, and public tours. During this period, we could freely engage with the public and there were no restrictions in terms of visiting and hosting the public at the observatories in Cape Town and Sutherland.

Teacher training, support and development

A total of 72 teachers in three different events were reached in this period. One teacher development session was held in January which attracted 30 teachers. The session was based on the theme "Earth and Beyond" and is intended to support the natural science teachers in the teaching of astronomy concepts and phenomena. These sessions are also intended to provide teachers with educational resources which they can use in their classrooms. The SCBP staff participated in the Science Teacher day on 7 March, which was attended by 31 teachers. The objective of the Science Teacher day is to expose teachers to different approaches and ways of teaching physics and astronomy, as well as to promote careers in science and technology. The SAAO and SCBP staff also attended the Western Cape Curriculum Advisers meetings at the University of Stellenbosch in January, which reached 12 teachers. They were provided with opportunities to share information on the various teacher and learner-based programmes.

Learners activities

A total of 422 learners participated in various workshops and visited the Observatory in Cape Town. An outreach programme involving astronomers attending the 2020 IAU transient programme was implemented and the astronomers gave talks and facilitated workshops at the following schools: the Cape Academy, Vuyiseka High School, Zisukhanyo High School, and Thandokhulu High School. We also hosted the Astronomy inspired private girl's school called "Molo Mhlaba", which can be loosely translated to "Hello Earth". Cedar House and Labori High School visited the Sutherland Observatory. Auburn House and St Cyprian visited the Cape Town Observatory.

Public Engagement

During this period four open nights were held, reaching 273 people. They were addressed by professional astronomers and were taken on a tour of the Cape Town site and were given opportunities to view various objects through the historical McClean Telescope as well as some small Dobsonian Telescopes.

In Sutherland, a total of 1494 people visited and participated in the Day or Night Tours. These remain very popular among the general public of South Africa, as well as tourists.

COVID-19 high level restrictions: 27 March – 31 May

Concomitant with the COVID-19 pandemic outbreak came a total lockdown with stringent COVID-19 prevention protocols and restrictions (Levels 5 and 4) which rendered in-person engagement activities and site visits impossible.

To support the learning and teaching of Mathematics and Physical Science, SCBP staff acted as tutors and instructors in a "What's-App"-based programme geared towards supporting mathematics and science learners. This programme was implemented jointly with the Association in Educational Transformation.

A Zoom-based presentation followed by questions and answers was organised to celebrate the International Asteroid Day. The session was addressed by Dr Nicolas Erasmus and was intended for youth learners.

The programme "2020: Moments in the history of optical astronomy", initially intended as an in-person internal staff engagement, was changed to become an online programme. This involved sharing videos on: the history of astronomy in South Africa, the critical moments and discoveries, the professional astronomer's experience, reflections from the SAAO and SALT staff, and hopes and visions of young astronomers, engineers and observers of the observatory. The videos included the beneficiaries of our programmes in Sutherland and featured the schools and local clinic; they also included students who had previously participated in our successful job shadowing programme and are currently studying astronomy, physics, computer science or engineering at various universities. Selected videos were shared via social media with the general public.

A series of crossword, word-search and anagram puzzles based on the history, telescopes and research conducted at SAAO and SALT were developed and these were shared with SAAO staff and with the public via social media.

To further engage the public, since the open nights and public tours were suspended, astronomers were encouraged to record themselves giving a talk and to also provide a written summary of the talk. These were posted on the website and also shared via Twitter and Facebook. The aim was to continue sharing the relevance of our institution and to inform the public of astronomical developments and discoveries.

A media training forum was organised for the astronomers. This was organised by SCBP staff and focused on media releases and media relations, including the handling of radio and television interviews after a media release.

The staff of SCBP also participated in various online forums and discussions as panel members. These included the Africa Day celebrations, science and science engagement for scientists and researchers, career-based discussions, etc.

COVID-19 low level restrictions: June – December

With the relaxation of the lockdown conditions (Levels 1 – 3), we were able to roll out some programmes even though many were still online-based. An attempt was made to encourage the public to observe the bright planets in our solar system, and two solar eclipses. As part of the SAAO's 200-year anniversary, a "200 Days" festival was organised from 27 October to 20 December 2020, which included a series of weekly zoom-based seminars.

Eclipses

The solar annular eclipse on 21 June 2020 was visible to the African continent, though South Africa saw only a partial eclipse. In support of this event, SCBP staff distributed solar filters and solar viewers to interested parties and organisations in various African countries, partly in collaboration with AfAS (African Astronomical Society).

Similar efforts were undertaken with the partial solar eclipse of 14 December 2020, which was only visible to the south-western regions of Africa. Solar viewers were distributed to science centres, amateur astronomers and the general public in Cape Town. The public was encouraged to observe the eclipse, but unfortunately the weather was not favourable for many South African towns and cities.

The great planetary conjunction

On 21 December 2020, we observed the great planetary conjunction of Jupiter and Saturn. SCBP staff and post-graduate students volunteered to translate posters into various South African indigenous languages – these were shared and distributed via social media. The public was encouraged to observe the planetary conjunction, but the weather was again not favourable for many towns and cities. SCBP staff and the science engagement astronomers fielded various radio interviews in a bid to communicate and share the relevance of the planetary conjunction.

Astronomy Quiz

This year, an astronomy quiz for grade 7 learners was implemented jointly with the ArcelorMittal Science Centre and the South African Agency for Science and Technology Advancement (SAASTA). Unlike previous years when we implemented the quiz nationally, this was confined mainly to the town of Newcastle and was completely done online. Thanks to Dr Christian Hettlage for all the technical support provided. All the participants received certificates of participation and the winners received some prizes.

South African – Zambian STEM career and role modelling project

A joint collaboration between South Africa and Zambia focusing on careers in STEM was held on 28 November. This was followed by a role modelling session for girls and included South African born scientists presenting to teachers and girl learners from South Africa and Zambia. This was preceded by a presentation from an SCBP staffer sharing her experiences with organising and implementing career activities for girl learners at high schools.

Zoom-based outreach for homeschoolers

A zoom-based programme intended to reach homeschoolers was organised and implemented. This involved Zoom-based presentations for foundation phase learners based on the Moon and its relationship with the Earth and the Sun. These groups of homeschoolers used to visit the Observatory pre-COVID-19.

The Cultural Astronomy project

A number of short video presentations by indigenous knowledge holders and professional indigenous researchers such as Prof. Keith Snedegar, Prof. Jarita Holbrook, Dr Motheo Koitsiwe, Mr Themba Matomela, and others have been collected and will form part of the African Cultural Astronomy CD. Further animated stories shared as part of the Moments in the History programme will also be part of the African Cultural Astronomy CD.

Job Shadow programme

COVID-19 also affected the job shadowing programme, since learners could not come on-site anymore. Instead, the programme manager, Ms Natalie Jones, asked students who attended the programme in previous years to record their reflections on the impact of the job shadow programme, that is, what they learned from the experience and how it affected their lives. All videos were done during lockdown, and will be made available on the SAAO webpage.

Sutherland Tours

With the relaxation in the lockdown conditions to Level 1 (21 Sep to 28 Dec), we were able to re-open the tours in Sutherland. Initially limited to drive-through tours with visitors allowed to take pictures at two pre-selected spots. A total of 61 cars were counted during this time. Later, in December, we were able to re-open the tours fully, though with limited numbers and COVID-19 prevention protocols such as social distancing and sanitisation of hands; 426 people were thus reached. With the re-introduction of higher level restrictions, we had to suspend the tours again. Tours will be constantly reviewed and assessed as regulations are confirmed by the President of the country.

Sutherland COVID-19 relief programme

We were able to distribute food parcels to indigent families of Sutherland through the financial support we received from the IAU OAD. With the support from the SAAO Director and the SALT Board, we intend to utilise the services of the Gift of the Givers (an NGO) in further distributing food parcels to the poor and indigent families.

200 Days Festival 2020

As part of the bicentenary celebrations of the SAAO, a 200 Days festival was organised, starting on 27 October. The aim of the festival was primarily to share the beauty, relevance, and power of astronomy, as well as to highlight and celebrate the contributions and achievements of South African astronomy. Some of its objectives were to increase the participation of the broader public and to continue with the Bicentenary activities beyond the anniversary's day, 20 October. In this vein, competitions have been organised for the youth in Sutherland, teachers nationally, and foundation phase learners nationally. Furthermore, we are in the process of employing a mathematics teacher for the two Sutherland schools, thanks to the SALT Board.

From 27 October – 20 December, a series of weekly seminars and panel discussions was organised. They were open to all members of the public, and we were overjoyed to see international audiences participating in the various webinars sharing their experiences. The panellist and presenters were drawn from various astronomy and science institutions and included presenters from Australia, Portugal, Germany, Poland, Uganda, and many other countries. The themes included: indigenous astronomy, astronomy and science education, careers in astronomy, astro tourism, Sutherland tourism and development, astronomy in science centres, and online learning and teaching.

As part of the festival, members of the general public were encouraged to observe the planets in our solar system, take pictures and share them with the SAAO staff and the public, as well as encourage family members to participate. This was dubbed the Planet Chase and it was exciting to observe the Sutherland-based staff and families taking up the challenge and sharing various images of these objects. Furthermore, professional astrophotographers joined in and took beautiful pictures of Uranus and Neptune which were shared with the public.

Thanks to the SAAO Director and the SALT Board, we will also be able to offer undergraduate bursaries to Sutherland and Northern Cape students in science, engineering, tourism and education.

Word of Gratitude and Acknowledgement

We would like to thank our SALT partners for all their assistance in the execution of education and outreach programmes. We would also like to thank the SAAO executive and the Director, Prof. Petri Väisänen for the support of the science engagement programmes. SCBP's manager, Mr Sivuyile Manxoyi, wishes to extend words of gratitude to all SCBP staff members for all their contributions and hard work that has made this year a success. Thanks too to all SAAO staff and all astronomers that supported our efforts.

OUTREACH & EDUCATION

SALT outreach programmes

SAAO Bicentenary

2020 saw the 200-year anniversary of the SAAO. In light of the current COVID-19 pandemic the proposed plans for October 2020, namely, the unveiling of the SAAO as a National Heritage Site, the SAAO 200 Astronomy Symposium, and the SAAO 200 Astronomy Festival had to be reimagined to fit with the current situation.

The week of 20 October kicked off with the premiere of the new SAAO/SARAO full-dome planetarium film, Rising Star. It was produced by Dr Daniel Cunnama (SAAO) and Dr Sally Macfarlane (UCT) and is Africa's first full length locally produced planetarium film on South African astronomy. The film leads the audience on an astronomical journey from the beginnings through the development of astronomy research in South Africa and looks at what the future holds for the country. It highlights the many remarkable facilities hosted in South Africa along with some of their latest results.

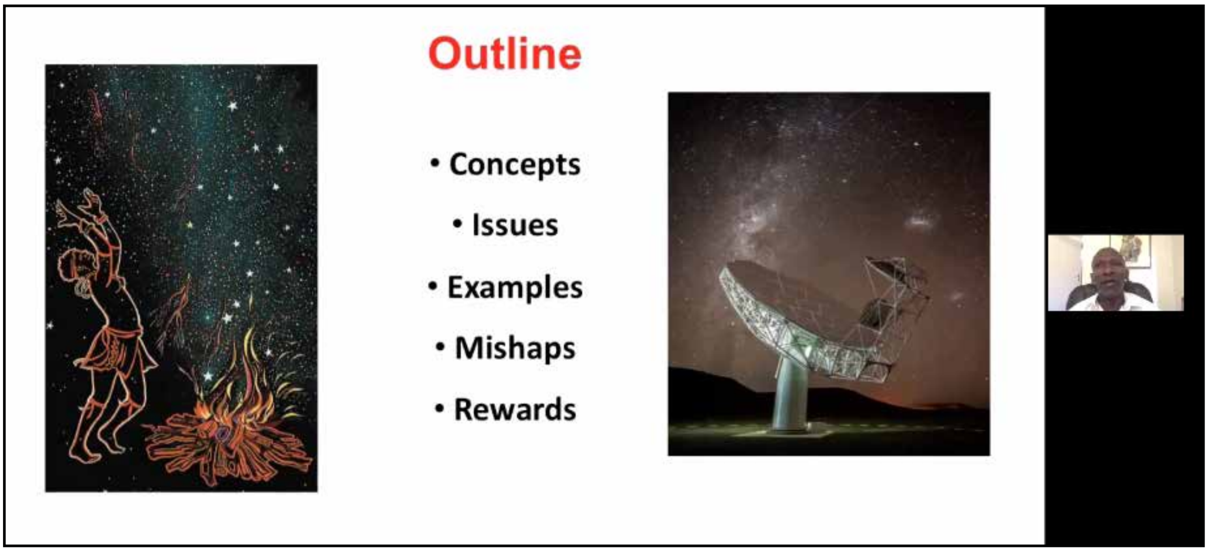
The evenings of 19 and 20 October saw the SAAO Main Building illuminated with a large South African flag and the formal unveiling of the SAAO as National Heritage Site was held on the bicentenary day on 20 October 2020. The event was attended by a very limited number of dignitaries including DSI Director-General, Dr Phil Mjwara and SAHRA CEO Adv Lungisa Malgas. The unveiling included prerecorded addresses by the Minister of Sports, Arts and Culture: the Honourable Nkosinathi Mthethwa and Minister of Higher Education and Training, Science and Innovation, the Honourable Dr B.E. Nzimande. Aside from interviews with SAAO staff, the programme included the premiere of a new animation of indigenous Khoesan starlore "Moons Message" which was very well received. The Livestream of the unveiling was viewed by over 1000 people and was featured on SABC, EWN news channels and various newspapers.

Dr Phil Mjwara, Dr Luyanda Mpalhwa, SAHRA Chief Executive Officer Adv Lungisa Malgas , SAAO MD Prof. Petri Väisänen

DSI Director-General, Dr Phil Mjwara, unveils the bicentenary plaque

SAAO 200 Symposium

The SAAO 200 Symposium ran from 20 – 23 October as an entirely virtual event, a first for SAAO. There were over 600 registrations with 75% coming from South Africa. The talks covered a wide range of topics, including current and future science, the history of astronomy on the continent, as well as cultural and sociological aspects of astronomy. The symposium also aimed to highlight the developing plans for the transformation of the SAAO observatory. Highlights were addresses by SAAO Director Prof. Petri Väisänen, SARAO Director Dr Rob Adam, and IAU President Prof Ewine van Dishoeck. The talks were recorded and have been made available in perpetuity on the SAAO Website.



Virtual Festival

During the same week, the SAAO hosted, in collaboration with Scifest Africa, a joint Virtual Festival for the public to celebrate Astronomy and Space Sciences. The SAAO Virtual Festival saw a series of small events each week in October, culminating in the online virtual festival from Tuesday to Friday 20 – 23 October 2020. Highlights of the public programme were virtual storytelling hosted by Dr Gcina Mhlope, who dazzled us with beautiful narrations of the African night sky, live evening talks, presentations and lectures on astronomy and space science, workshops for learners, parents and educators. In total 13 events were held with an estimated attendance of over 1500 individuals. Finally, the Virtual Festival came to a close with a night of live virtual stargazing and good music hosted by Master KG of the hit single Jerusalema.

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 and one member from each of the remaining partner institutions. 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. Michael Shara (Chair)
American Museum of Natural History, USA

Prof. Matthew Bershady
University of Wisconsin–Madison, USA

Prof. Gerald Cecil (Resigned 29/05/2020)
University of North Carolina at Chapel Hill, USA

Prof. Brian Chaboyer
Dartmouth College, USA

Prof. Phil Charles
United Kingdom SALT Consortium, UK

Dr Lisa Crause (Resigned 31/05/2020)
National Research Foundation, South Africa

Prof. John P. Hughes
Rutgers University, USA

Prof. Shazrene Mohamed (Appointed 01/06/2020)
National Research Foundation, South Africa

Dr Molapo Qhobela (Resigned 13/11/2020)
National Research Foundation, South Africa

Prof. Somak Raychaudhury
Inter–University Centre for Astronomy & Astrophysics, India

Prof. Marek Sarna
Nicolaus Copernicus Astronomical Centre, Poland

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.

SALT is operated on behalf of the SALT Foundation by SAAO and managed by the SAAO Director, Prof. Petri Väisänen. With the exception of Mrs Lizette Labuschagne, the staff who carry out the day-to-day operational activities are SAAO employees. Engineering operations are managed by the SALT 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 5 Board members. In this reporting period, they were: Prof. Mike Shara (Chair), Prof. Brian Chaboyer, Prof. Phil Charles, Prof. Jack Hughes and Prof. Somak Raychaudhury.

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 and Mrs. Kate Soule.

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: Paul Groot, Matt Bershady, Hermine Schnetler, John Booth, Joanna Mikołajewska, David Buckley, Raghunathan Srianand and Lisa Crause (Chair).

Technical Operations Team 2020

Paul Rabe (Head)

Richard Banda

Janus Brink

Keith Browne

Bryne Chipembe*

Alrin Christians

Willa de Water

Timothy Fransman

Denville Gibbons

Johan Hendricks

Stephen Hulme

Nicolaas Jacobs

Sunnyboy Kabini*

Anthony Koeslag

Jonathan Love

Deneys Maartens

Thabelo Makananise

Adelaide Malan

Melanie Saayman

Etienne Simon

Ockert Strydom

Nicolaas van der Merwe

Eben Wild

Astronomy Operations Team 2020

Encarni Romero Colmenero (Head)

Danièl Groenewald

Christian Hettlage

Alexei Kniazev

Thea Koen

Enrico Kotze

Marissa Kotze*

Rudi Kuhn

Nhlavutelo Macebele

Fred Marang

Moses Mogotsi

Sifiso Myeza*

Anja Schröder*

Rosalind Skelton

Lee Townsend*

Veronica van Wyk

Lonwabo Zaula

SALT Observatory Scientist 2020

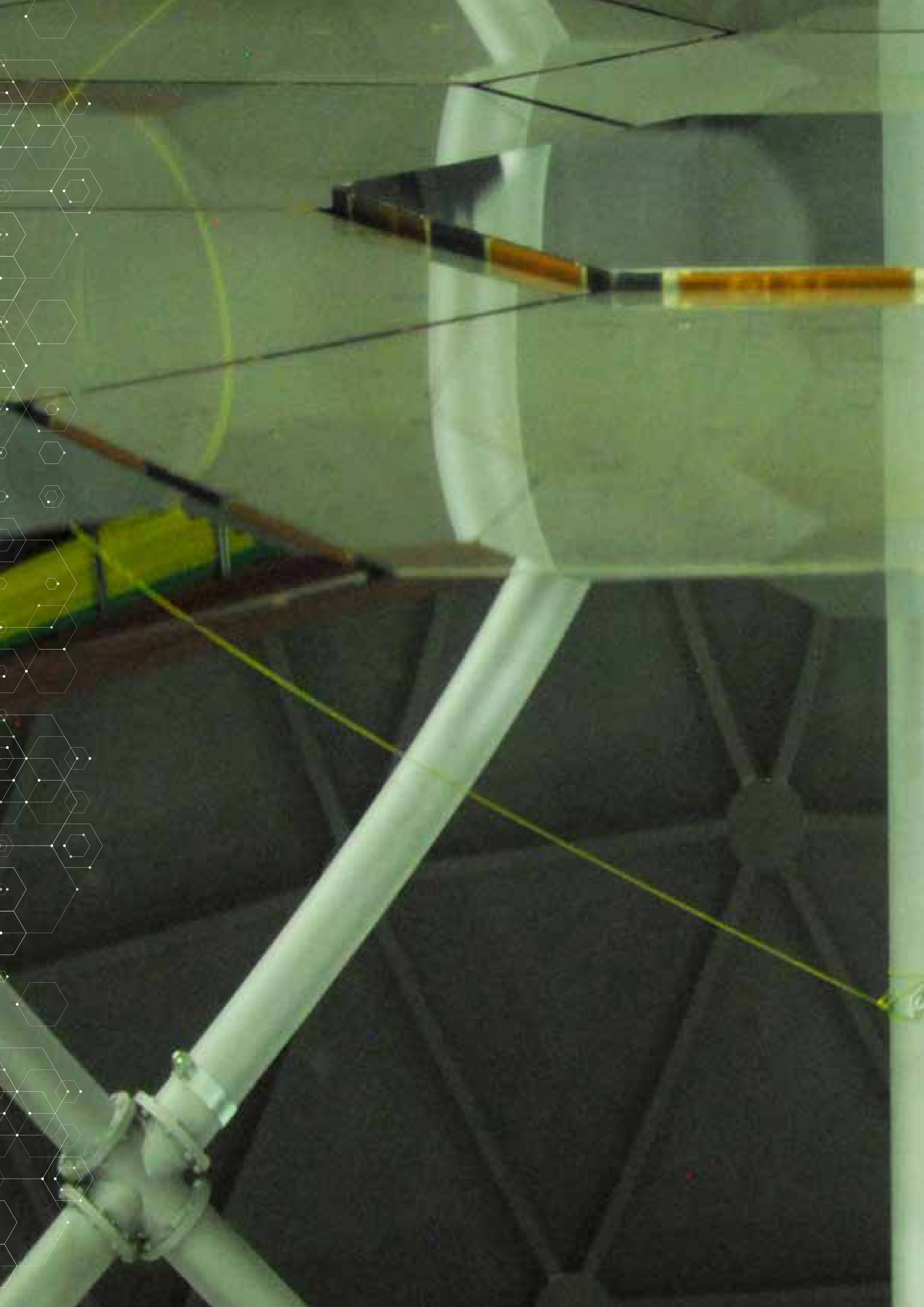
Lisa Crause

Corporate Governance Team 2020

Lizette Labuschagne

Surayda Moosa

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



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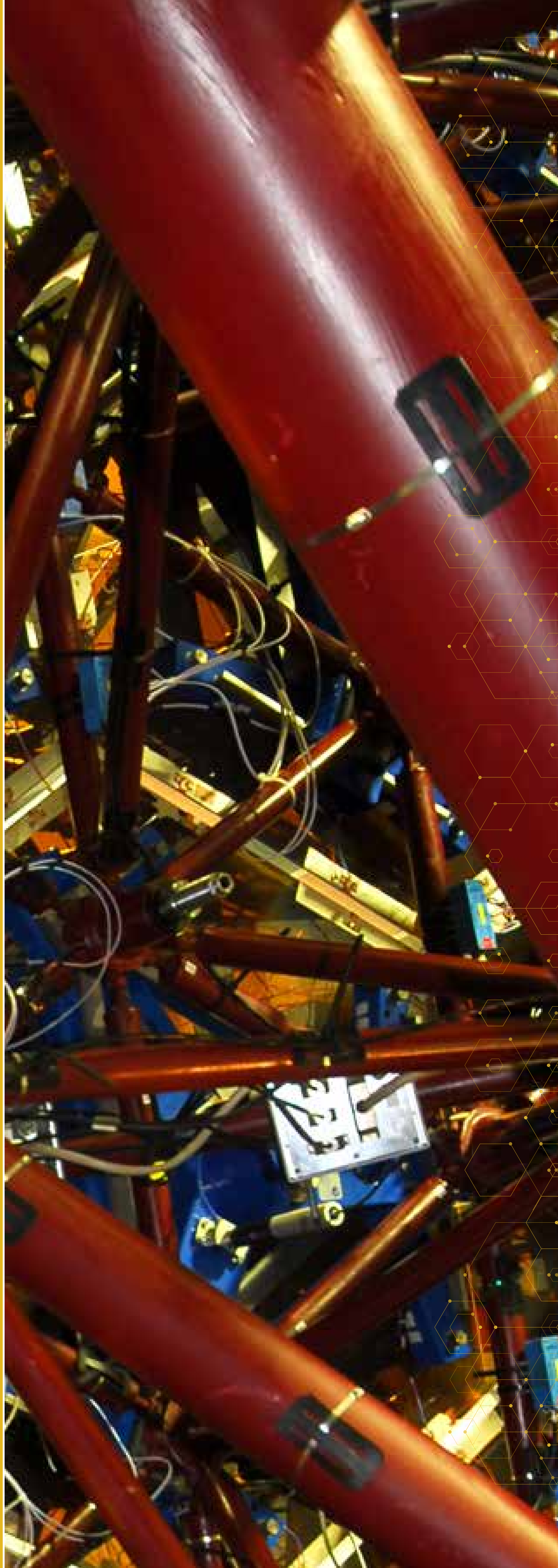
GLOSSARY



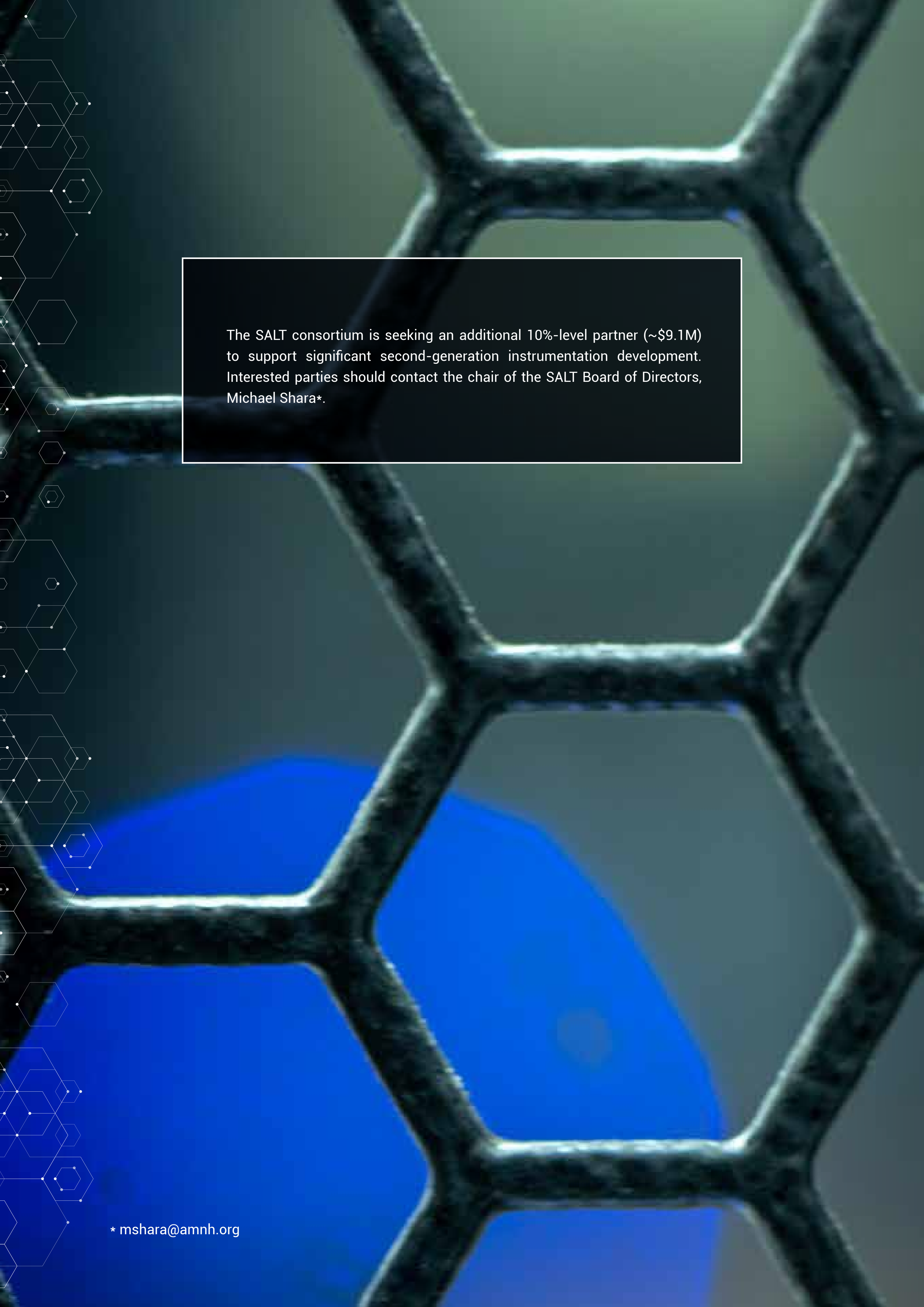
Glossary & Acronyms

ADC	atmospheric dispersion compensator
AfAS	African Astronomical Society
AGB	asymptotic giant branch
AGN	active galactic nucleus
AMNH	American Museum of Natural History
API	application programming interface
ARC	Astronomical Research Cameras
ASASSN	All Sky Automated Survey for SuperNovae
BEC	board executive committee
BMS	building management system
BRITE	BRIght-star Target Explorer
CAMK	Nicolaus Copernicus Astronomical Center
CCD	charge-coupled device
CEO	Chief Executive Officer
CD	compact disk
Co–I	co–investigator
CoV	coronavirus
COVID-19	coronavirus disease 2019
CTA	Cherenkov Telescope Array
CTS	Calan Tololo Survey
CV	cataclysmic variable star
DC	Dartmouth College
DDT	director's discretionary time
DR	data release
ESA	European Space Agency
ESO	European Southern Observatories
EWN	Eyewitness News
FAC	finance & audit committee
FIF	fibre instrument feed
FP	Fabry–Pérot
GATS	Global Astrophysical Telescope System
GSM	Global System for Mobile communications
GTC	Gran Telescopio Canarias
GWP	gravitational wave programme
H2RG	HAWAII–2RG detector
HARPS	High Accuracy Radial Velocity Planet Searcher
HD	Henry Draper
HE	Hamburg–ESO survey
H.E.S.S.	High Energy Stereoscopic System
HET	Hobby–Eberly Telescope
HIF	H-ingestion flash

HMI	human machine interface
HR	Hertzsprung-Russell
HRS	high-resolution spectrograph
HS	high-stability
IAO	Institute Astronomical Observatory
IAU	International Astronomical Union
IFU	integral field unit
ISDEC	IUCAA SIDECAR Drive Electronics Controller
ISI	international scientific indexing
ISM	interstellar medium
IUCAA	Inter–University Centre for Astronomy & Astrophysics
JD	Julian date
KAT	Karoo Array Telescope
LADUMA	Looking At the Distant Universe with the MeerKAT Array
LFC	laser frequency comb
LIGO	Laser Interferometer Gravitational wave Observatory
LIRG	luminous infrared galaxy
LMC	Large Magellanic Cloud
LOFAR	LOw Frequency ARray
LSST	Large Synoptic Survey Telescope
LTE	Long Term Evolution
M1 … M5	mirror in the SAC
MASTER	Mobile Astronomical System of the TElescope–Robots network
MaxE	Maximum Efficiency spectrograph
MAXI	Monitor of All-sky X-ray Image
MDM	Michigan–Dartmouth–MIT observatory
MGPN	Morgan+Good PN
MJD	modified Julian Date
MSAC	mini-spherical aberration corrector
MT	mini tracker
NCAC	Nicolaus Copernicus Astronomical Center
NGC	New General Catalog
NGO	Non-Governmental Organisation
NICER	Neutron Star Interior Composition Explorer
NIR	near-infrared
NRF	National Research Foundation
NWU	North–West University
OAD	Office of Astronomy for Development

OGLE	Optical Gravitational Lensing Experiment
P0 … P4	priority 0 – 4
PAS	Polish Academy of Sciences
PI	principal investigator
PIPT	Principal Investigator Proposal Tool
PN	planetary nebula
POL	Poland
PoWR	Potsdam Wolf–Rayet
PR	public relation
PRV	precision radial velocity
RDP	Remote Desktop Protocol
RINGS	RSS Imaging spectroscopy Nearby Galaxies Survey
RL	radius-luminosity relation
roAp	rapidly oscillating Ap stars
RSA	Republic of South Africa
RSS	Robert Stobie Spectrograph
RU	Rutgers University
SA	SALT Astronomer
SA	South Africa
SAMMI	SALT Astronomer Man-Machine Interface
SAAO	South African Astronomical Observatory
SAASTA	South African Agency for Science and Technology Advancement
SAC	Spherical Aberration Corrector
SAI	Sternberg Astronomical Institute
SALT	Southern African Large Telescope
SALTICAM	SALT Imaging CAMera
SARAO	South African Radio Astronomy Observatory
SARS	severe acute respiratory syndrome
SAX	Satellite for X-ray Astronomy (BeppoSAX)
SCBP	SALT Collateral Benefits Programme
S–CUBED	Swift SMC Survey
SDA	SALT data archive
SDC	Structure and Dome Controller
SDSS	Sloan digital sky survey
SHOC	Sutherland High-speed Optical Cameras

SIDECAR	system image, digitizing, enhancing, controlling, and retrieving
SKA	Square Kilometre Array
SMC	Small Magellanic Cloud
SMP	Sanduleak+McConnell+Philip
SN	supernova
SNR	supernova remnant
SO	SALT Operator
SPIE	Society of Photo–optical Instrumentation Engineers
SPS	(mirror) segment positioning system
SpUpNIC	Spectrograph Upgrade: Newly Improved Cassegrain Instrument
SSWG	SALT science working group
STC	scientific and technical committee
STEM	science/technology/ engineering/mathematics
SwSt	Swings+Struve
SySt	symbiotic system
TCS	Telescope Control System
TESS	Transiting Exoplanet Survey Satellite
TMT	Thirty Meter Telescope
U	university
UCLan	University of Central Lancashire
UCT	University of Cape Town
UKSC	United Kingdom SALT Consortium
UNC	University of North Carolina – Chapel Hill
UPS	uninterruptable power supply
UV	ultraviolet
UVES	Ultraviolet and Visual Echelle Spectrograph
UW	University of Wisconsin–Madison
UWC	University of the Western Cape
VIS	visible
VLT	Very Large Telescope
VNC	virtual network computing
VPN	virtual private network
VV	Vorontsov-Velyaminov
[WC] = WR-CSPN	Wolf–Rayet central star with PN
WD	white dwarf
WISE	Wide-field Infrared Survey Explorer
WR	Wolf–Rayet
XMM	XMM–Newton observatory
XMMU	unique XMM source
XRT	X-Ray Telescope



The SALT consortium is seeking an additional 10%-level partner (~$9.1M) to support significant second-generation instrumentation development. Interested parties should contact the chair of the SALT Board of Directors, Michael Shara*.

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