SOUTHERN AFRICA LARGE TELESCOPE

ANNUAL REPORT 2018

MESSAGE FROM THE SAAO DIRECTOR

The SALT Foundation has entrusted the operation of SALT to the South African Astronomical Observatory, SAAO. The SAAO is the major optical astronomical research institute in Africa, one of the National Facilities of the National Research Foundation (NRF), which in turn is the largest shareholder in the SALT partnership.

SAAO thus plays multiple roles, from operating SALT and influencing SALT developments as the major partner, to utilising the telescope for the science of its own researchers. We also make a concerted effort to increase the use of SALT within the (South) African scientific community, as well as for student training through local universities, and as a platform for science engagement.

The assorted roles that SAAO plays makes life in the organisation complex, and exciting. Of the approximately 130 SAAO employees, more than 30 are directly involved in SALT Operations, with many more contributing other technical and administrative support functions, as well as using it for their research.

Importantly, regardless of the nominal individual job descriptions, I see SAAO and SALT as inseparable. Now, more than ever, one of them would not make much sense without the other.

The year 2018 highlighted this trend. The major SALT related development was SAAO reaching an agreement with SARAO (the SA Radio Astronomy Observatory, previously SKA-SA, our sister National Facility), where SARAO will fund a so-called Generation 1.5 SALT Instrumentation package. The package includes the MaxE spectrograph and an HRS High-Stability mode upgrade, both discussed later in this Annual Report, along with the initial development of an "Intelligent Observatory" concept. I am particularly excited about the latter long-term project, which ultimately aims at converting the whole Sutherland observing plateau (including two dozen telescopes, with SALT at its apex) into a single machine: an intelligent automated network with a large suite of instruments capable of rapidly reacting to triggers from the Transient Universe. Both SAAO and SALT see this as an exciting area where we can contribute to cutting-edge developments of world-wide astrophysics in the 2020s.

Apart from the beginning of the first major new instrument development for SALT since the first generation of instruments, the "Gen 1.5" project intricately links South African engineering expertise and development to that of the SALT project. Local scientists and engineers will build new instruments, and the SAAO Instrumentation Division and the SALT Technical Team will work together.

I wish to sincerely thank the goodwill of the senior SARAO management and the strong support of the NRF for this, and the excellent groundwork of the SALT Ops Team in putting together an exciting proposal with well-motivated budgets. Also, the Gen 1.5 project could not have been possible without a clear and believable science strategy that the SALT Board ratified in 2018.

Petri Väisänen

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ABOUT SALT

ABOUT SALT

The Board of the Southern African Large Telescope (SALT) is proud to present its Annual Performance Report for the period 1 January 2018 to 31 December 2018. 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 is the major shareholder with a ~35 percent stake. Other large shareholders are the University of Wisconsin–Madison, the Nicolaus Copernicus Astronomical Centre of the Polish Academy of Sciences, Dartmouth College and Rutgers University. Smaller shareholders include the Indian Inter–University Centre for Astronomy and Astrophysics in India, the American Museum of Natural History, the University of North Carolina and the UK SALT Consortium, 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), have recently left the SALT Foundation, though the latter still received telescope time in 2018. The SALT Foundation is currently looking for new shareholders.

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

VISION

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

MISSION

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

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

STRATEGIC OBJECTIVES OF SALT

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 has completed another very productive year, with 45 peer-reviewed papers published (nearly a record), despite a month-long engineering shutdown and some mediocre winter weather. Data are being delivered to users within 24 hours via pipelines that are functioning smoothly. Daily updates are now available online to all partners on the status of each science program being executed by SALT.

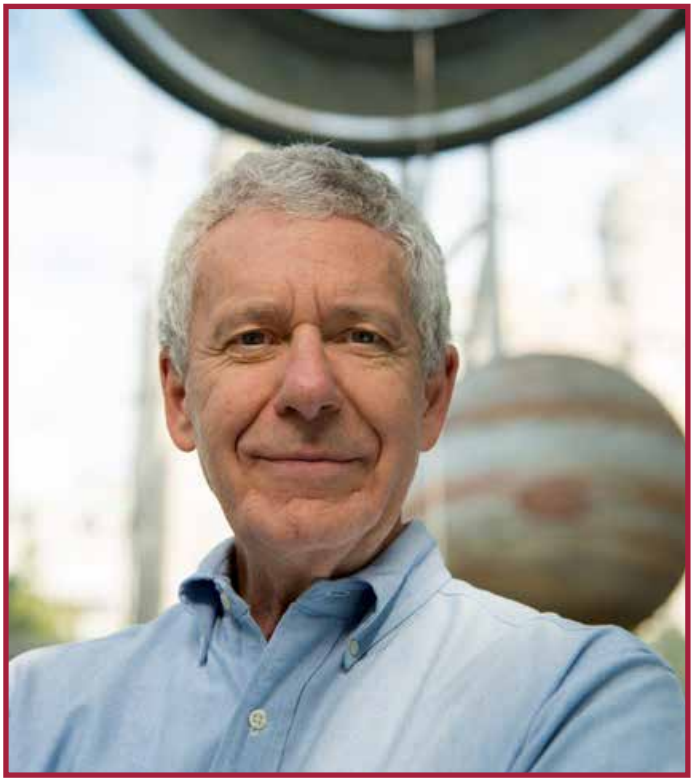
A strategic plan for SALT, strongly advocated by our Review Committee, has been formulated, adopted by the SALT Board and posted to the SALT website. A great deal of discussion and planning is now underway for major upgrades to the telescope's instrumentation.

A new RSS guider has been installed and commissioned. It allows acquisition of guide stars up to two magnitudes fainter than the previous guider, saving several minutes during target acquisitions. The HRS High-Stability mode has been tested, and shown to be capable of producing 5 m/s precision. Further tests and enhancements are underway.

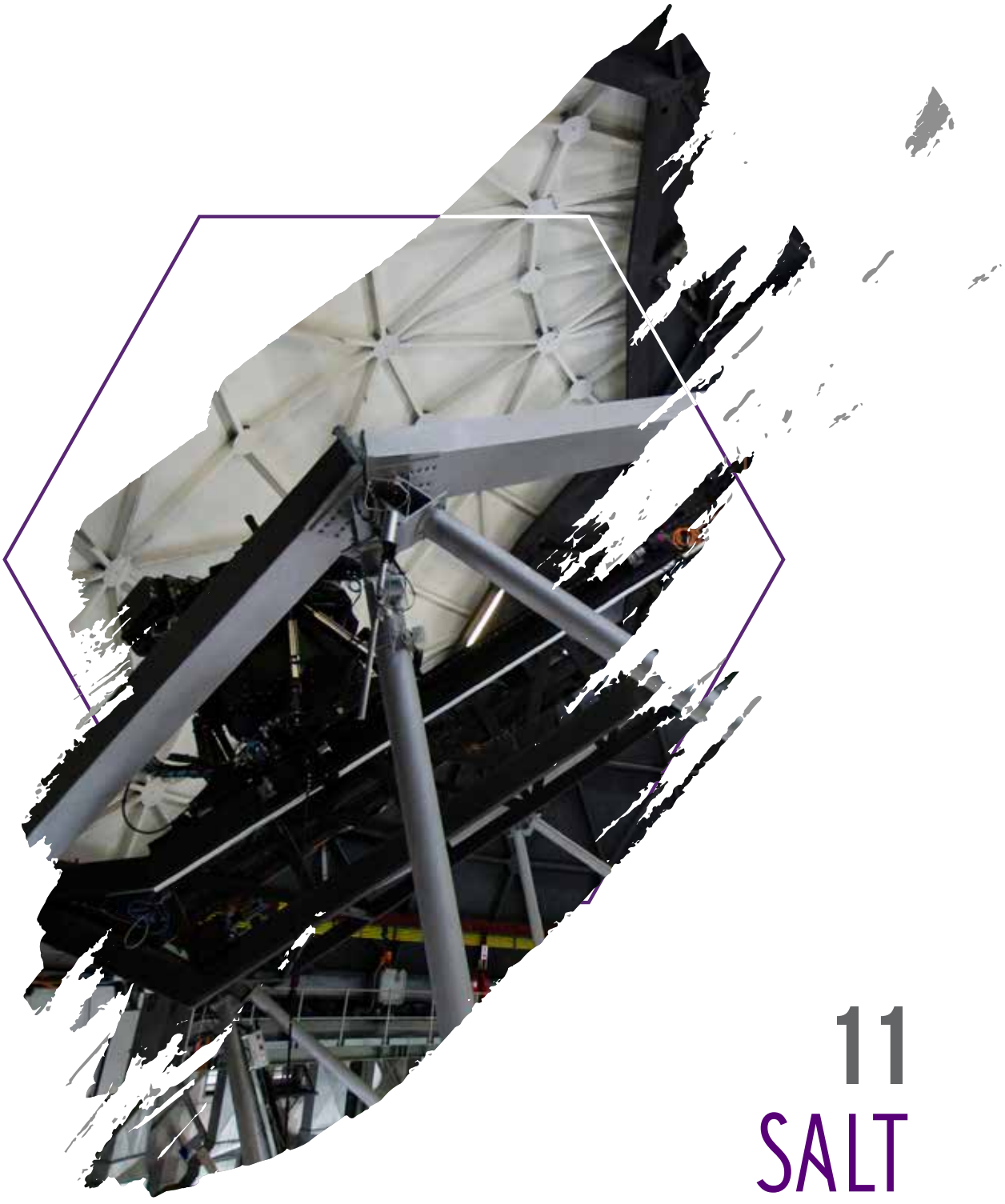
A high throughput low-resolution spectrograph, possibly based on a spherical grating conceived by Darragh O'Donoghue and Chris Clemens, is fully funded and being designed. Deployment is planned for 2021, with throughput gains over current instrumentation of up to a factor of two being anticipated.

A new SALT Observatory Scientist position has been created, with Lisa Crause being the first astronomer appointed with that title. Many new staff have been recruited and added to both Astronomy Operations and Technical Operations. A Scientific and Technical Committee has been established to critically examine all aspects of SALT, and to recommend methods to improve operations and instrumentation.

The financial status of SALT is strong. To ensure a steady stream of new instrumentation beyond 2021, and to further strengthen the Observatory's financial state, one new partner at the 10% level of ownership is being sought by the Board.



Prof. Michael Shara
Chairperson, SALT Board



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SALT PARTNERS

INTRODUCTION

SALT is an international consortium consisting of a small 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 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 ~$1900/h). It may also be in the form of the highest priority time only, which is guaranteed to be observed fully, at twice that rate. 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 (~$8.8M) to support significant second-generation instrumentation development. Interested parties should contact the chair of the SALT Board of Directors, Michael Shara.

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 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 electronic departments at SAAO's 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 is 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 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 about two hundred Ph.D. 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, 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 | Lisa Crause, SAAO/SALT

UNIVERSITY OF WISCONSIN–MADISON (USA)

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

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

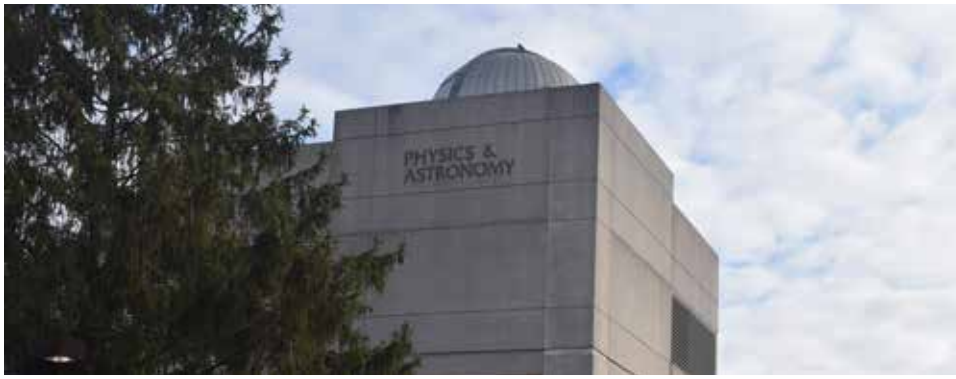
One of two doctorate-granting universities in the University of Wisconsin system, UW–Madison has the specific mission of providing "a learning environment in which faculty, staff and students can discover, examine critically, preserve and transmit the knowledge, wisdom and values that will help insure 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 member: Eric Wilcots

The astronomy department group on top of their building.

RUTGERS UNIVERSITY (USA)



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

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 then 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 1990's 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.

SALT Board member: Jack Hughes

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.

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

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 fall 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 J. 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 Scientific and Technical Committee, being highly involved in this and other SALT committees. There are five main SALT partner institutions.

The Nicolaus Copernicus Astronomical Center (CAMK, or NCAC in English) of the PAS is the leading astronomical institute in Poland. It is located in Warsaw and was established in 1978. At present, 57 scientists are working at CAMK along with 35 Ph.D. 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 at institutes, observatories and universities 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 Magellanic Clouds and the study of individual systems; novae; post AGB binaries and dark matter studies using spectroscopic long term monitoring of selected quasars.

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

The Center for 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 planetary nebulae.

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 astro-seismology). Observations are conducted with a coronagraph located near Wrocław and with SALT (among others), respectively. Satellite observations play an important role in these investigations as well.

Left: CAMK Warsaw | Right: CAMK Toruń

SALT Board member: Marek Sarna, CAMK

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 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 disk 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 extra-galactic 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 6 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 post-docs to SA. Furthermore, UKSC has successfully hosted a half-dozen SALT Stobie scholarships, greatly enhancing the production of South African astronomy Ph.D.s. In 2017, the consortium was awarded "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. Our science interests and activities are as follows.

SALT scientists at the **University of Central Lancashire** (UCLan) include Gordon Bromage, Anne Sansom, Don Kurtz and Dan Holdsworth. Bromage was UKSC's previous Board director and has been also 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.

At the **Open University**, science interests range from the "Dispersed Matter Planet Project" (Carole 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 (Andrew Norton, Marcus Lohr). Stephen Serjeant and Lucia Marchetti from 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.

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 Simon Jeffery, Michael Burton, Gavin Ramsay, Jorick Vink and Gerry Doyle.

At **Keele University**, Jacco 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 **University of Nottingham** has had significant involvement in SALT administration (UKSC Board director for 4 years and Chair of the Finance & Audit Committee (FAC) for 3 years), as well as funding a post-doc (6 months) and two graduate students (2 months each) to work on technical and software development for SALT. Science interests (Peter Sarre) are in molecular astrophysics and galaxies, making observations with RSS (long-slit and Fabry–Pérot) and HRS.

Phil 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", where they 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. The ASTROSAT observations include another major SALT partner, India. Mark 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–CUBE monitoring (Malcolm Coe). Also interested in SALT science are Christian Knigge, Diego Altamirano, Tony Bird and Poshak Gandhi.

SALT Board member:
Phil Charles, University of Southampton

UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL (USA)

The University of North Carolina at Chapel Hill (UNC) is the flagship research university and second largest of the campuses of the University of North Carolina System. Chartered in 1789, the university first enrolled students in 1795, making it one of three schools to claim title as the oldest public university in the United States. UNC offers degrees through 14 colleges and the College of Arts and Sciences to almost 30,000 students from North Carolina (minimum 85%) and the other U.S. states, as well as from other countries. The campus covers 3 km^2 of Chapel Hill's downtown and is one arm of North Carolina's tech-heavy Research Triangle, the other arms defined by Duke University (Durham) and North Carolina State University (Raleigh). The Morehead Planetarium and Science Center on the UNC campus features a digital projector and professional, fully robotic 0.6-m aperture research telescope with CCD cameras and spectrograph. The telescope is part of the global Skynet telescope network developed and run from UNC.

Astrophysics research at UNC is conducted by two theoretical cosmologists, two experimental nuclear astrophysicists, five observational astronomers, a general relativist, and a gas dynamicist. These faculty are joined by a half dozen post-doctoral fellows and by approximately 25 graduate students. Many efforts focus on the SOAR 4.1-m telescope on Cerro Pachon in Chile that all use remotely from UNC. Its Goodman spectrograph, from which the SALT RSS was derived, was built in the extensive and modern machine shop in the Physics and Astronomy Department.

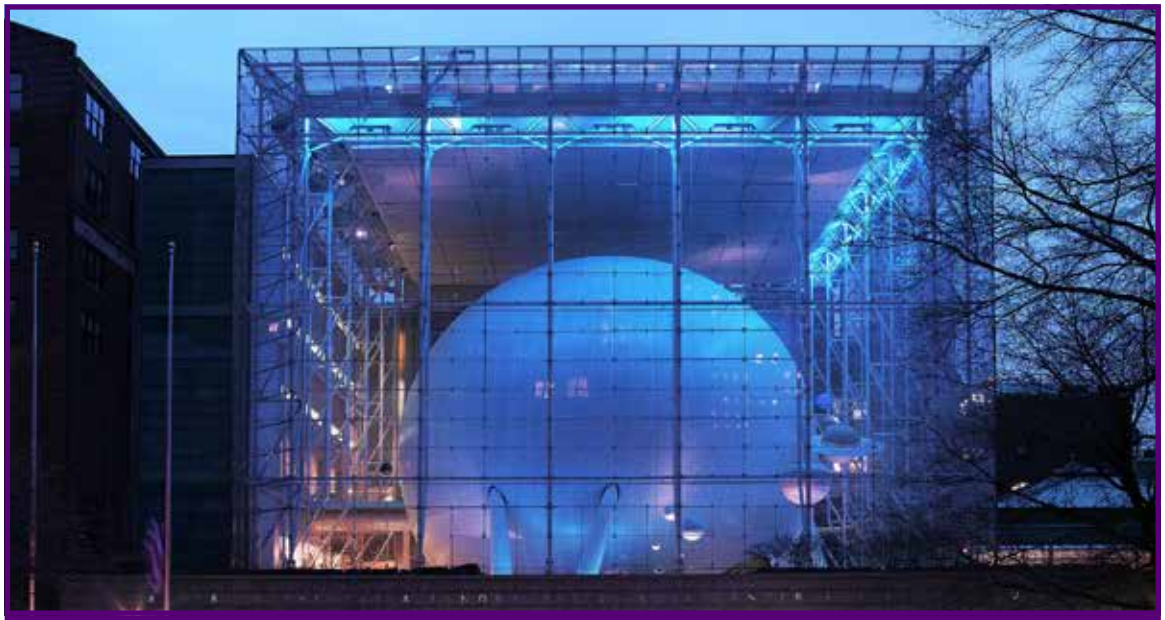
Nicholas Law's group at UNC plans to use SALT for exoplanet follow-up from their Evryscope and TESS surveys (TESS is NASA's next-generation, all-sky transit-detection satellite). The Evryscope is a 700-megapixel array of telescopes on a common mount that together image 8,000-square-degrees of the Southern sky every two minutes from CTIO in Chile. Evryscope is capable of confirming long-period large planets seen only once or twice in TESS's light curves. SALT's HRS will enable false-positive rejection and eventually mass measurements for dozens of planet candidates from the Evryscope and TESS. SALT's Fabry–Pérot capability is of particular interest to UNC astronomers because its wider field and more extensive wavelength coverage complements the Fabry–Pérot system behind SOAR's laser adaptive optics system.

Chris Clemens is working with the SAAO instrumentation group to explore the development of a high throughput spectrograph for SALT using the patented curved volume-phase-holographic gratings that he developed with the late Darragh O'Donoghue (SAAO). That is a major commitment to SALT's future because it will allow very efficient follow-up of time-variable targets from Evryscope and LSST. SALT time is open to everyone at UNC, with priority to student projects.

SALT Board member: Cecil Gerald

UNC's Evryscope located at Cerro Tololo in Chile.

THE AMERICAN MUSEUM OF NATURAL HISTORY (USA)



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

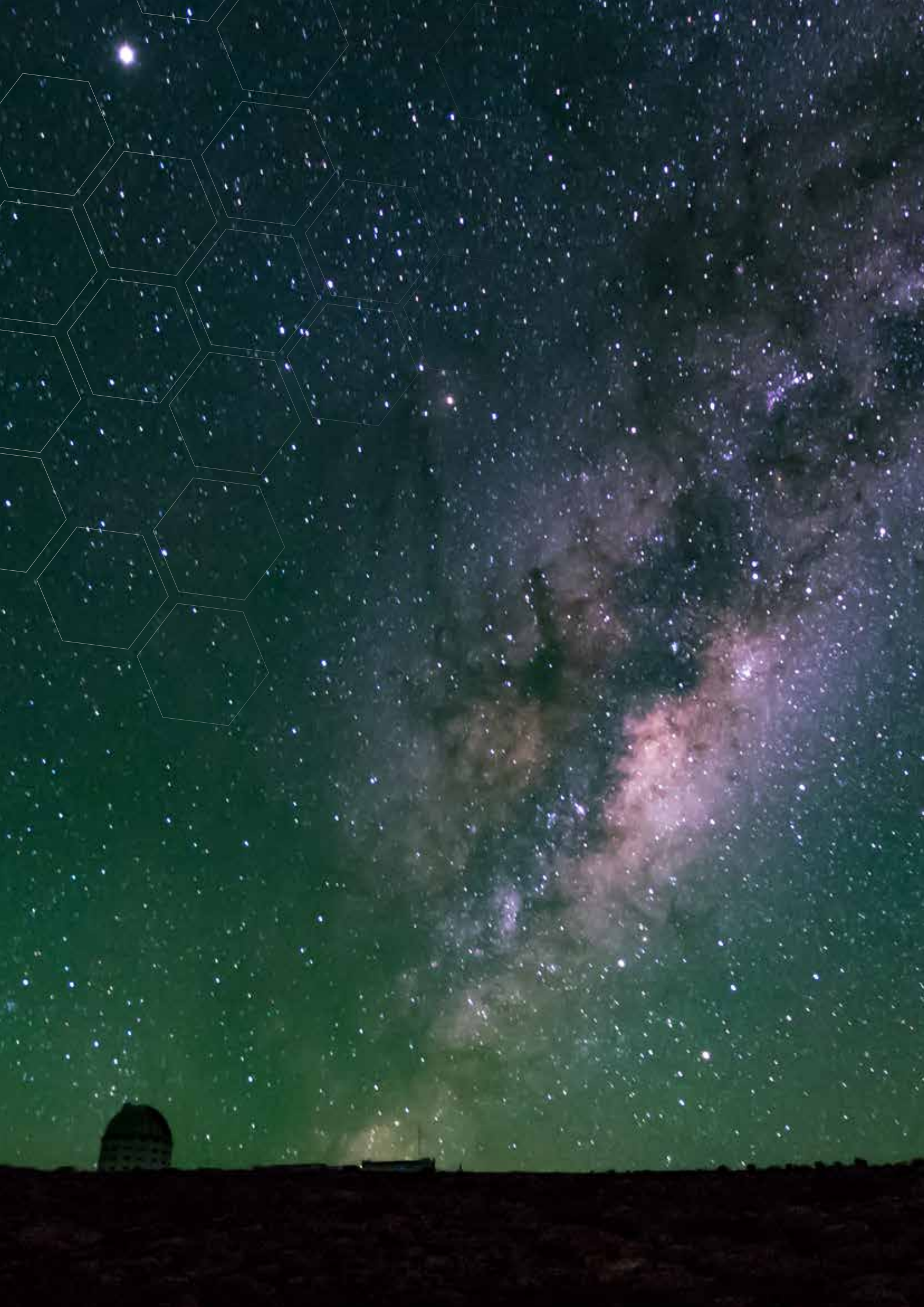
The American Museum of Natural History is one of the world's preeminent scientific and cultural institutions. Since its founding in 1869, the Museum has advanced its global mission to discover, interpret, and disseminate information about human cultures, the natural world, and the Universe through a wide-ranging program of scientific research, education, and exhibition. With 200 active researchers, including curator/professors, postdoctoral fellows, Ph.D. and Masters degree students, and research associates and assistants, AMNH is the only institution in North America that is both a research university and a museum, hosting over 5 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 fulldome video to project space shows based on scientific visualisation of current astrophysical data. A customized Zeiss Star Projector system replicates an accurate night sky as seen from Earth. The AMNH Astrophysics research department is responsible for the content of spaceshows, 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+WR star binaries – to high speeds.

AMNH Postdoctoral Fellow (and now Assistant Professor at the College of Charleston) Ashley Pagnotta has been using SALT to measure the brightnesses of novae observed over the past century to test whether they continue to fade until they become dwarf novae or fainter systems. She and research Associate Dave Zurek have also searched for nova shells around asynchronous, strongly magnetic cataclysmic binaries. Their non-detection is puzzling, and an important clue in understanding these binary stars.

SALT Board member: Michael Shara (chair)



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SCIENCE HIGHLIGHTS

Extragalactic astronomy

24

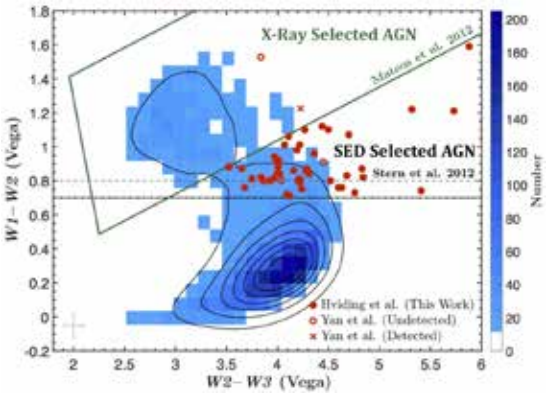
SCIENCE HIGHLIGHTS

SALT CHARACTERISES HEAVILY OBSCURED, MID-IR SELECTED QUASAR POPULATION

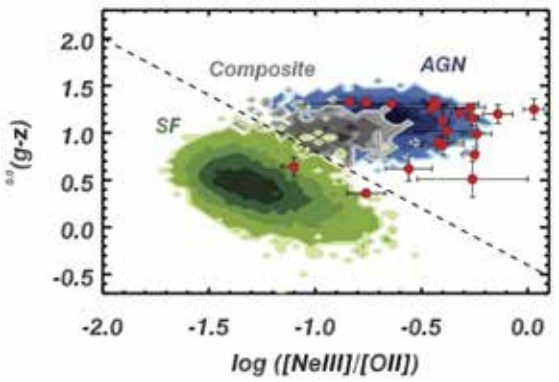
Active galactic nuclei (AGNs), that is, luminous galaxy cores powered by accretion onto a central supermassive black hole (SMBH), have played a prominent role in understanding galaxy evolution ever since the discovery of quasars, the most luminous AGNs. In particular, obscured (type II) AGNs can provide insight into the fuelling process and overall evolution of AGN activity, assuming the extinction occurs in the nuclear region. While unobscured (type I) AGNs are usually discovered using X-ray selection criteria, this technique often fails in the Compton-thick regime where most type II AGNs reside (N_H > 1.5 x 10^{24} cm^{-2}), being least effective for the most obscured ones.

A research group including Raphael Hviding at Dartmouth College decided to investigate mid-infrared (mid-IR) colour selection criteria to search for such hidden active SMBHs. The selected candidates obey a simple colour-cut criterion which had been discussed in the literature, but that lie outside a mid-IR colour wedge that had been defined previously based on an X-ray selected sample of type II AGNs.

SALT's queue-based observing style was considered ideal for characterising such a mid-IR selected sample. To determine whether the selection criteria indeed pick out heavily obscured AGNs, Hviding and his colleagues obtained longslit RSS spectra of 46 candidate AGNs and employed established diagnostics using excitation line ratios to determine the presence of an active SMBH. Making use of both the spectrum and the spectral energy distribution, they were then able to quantify both the dust in a galaxy's centre and the contribution of its central engine to the observed light. The right-hand figure shows that indeed nearly all candidates that have measured Ne III and O II emission lines lie in the AGN regime. They also noted that all these objects require a large optical-to-infrared extinction component in the models. The team thus verified that their method of using mid-IR colours is not only very successful in uncovering type II AGNs, but that they discovered a population of objects hosting highly obscured and actively accreting SMBH that have mid-IR colour combinations unusual for those that are detectable by current X-ray observatories.



The *WISE* colour–colour plot in Vega magnitudes. Selected candidates are plotted as filled red circles; typical error bars are shown in the bottom left corner. Open circles and crosses show X-ray detected and non-detected objects, respectively. Black and green lines indicate selection criteria published by other researchers. The blue 2D histogram with corresponding contours is based on a subset of SDSS-matched *WISE* sources that satisfy *WISE*-band *W4* magnitude cuts.



Colour–excitation plot for objects with O II and Ne III measurements/upper limits (filled red circles). Contours designate SDSS galaxies as star forming (green), composite (grey) and as AGN (blue).

Hviding, R.E., et al., 2018/02, MNRAS 474, 1955: Characterizing the *WISE*-selected heavily obscured quasar population with optical spectroscopy from the Southern African Large Telescope

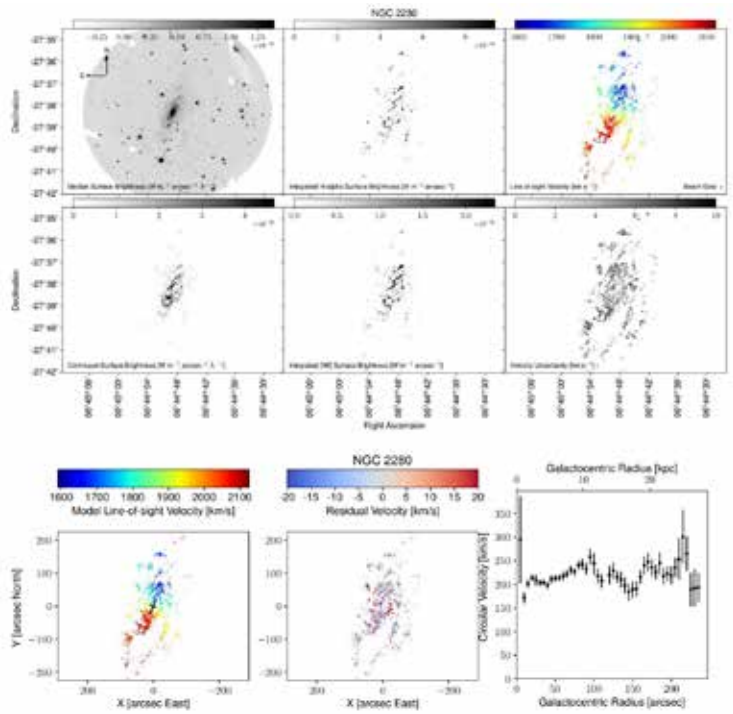
Hα FABRY–PÉROT KINEMATIC DATA SET OF NEARBY SPIRAL GALAXIES

The RSS Imaging spectroscopy Nearby Galaxy Survey (RINGS) was designed by a research group centred around Ted Williams at Rutgers University, New Jersey. The aim is to obtain high-resolution kinematic data to characterise the dynamics of 19 nearby, normal spiral galaxies, in order to understand the distributions of stars and gas and the structure of their dark matter halos (particularly on small spatial scales) in a cosmological context.

As part of the RINGS publication series, Ph.D. student Carl Mitchell presented the data, that is, the two-dimensional velocity fields for 14 of these nearby spiral galaxies. These results are based on over 19 hours of on-sky SALT observations, collected over a period of approximately five years beginning in late 2011, when the instrument first came online. These data are among the first published observations using the Fabry–Pérot spectrophotometric capability of the Robert Stobie Spectrograph (RSS).

In addition to extracting velocity field information from these 14 galaxies, the authors used the SALT Fabry–Pérot data to present detailed maps of the integrated Hα and N II emission in these galaxies. Axisymmetric kinematic models of these galaxies were generated using the DiskFit software package. These models were used to extract rotation curves and projection geometries for the observed galaxies. The rotation curves were then compared to other published rotation curves for the same galaxies. Furthermore, the projection parameters were compared to models of photometric observations of the same galaxies. The authors found that based on the comparison between the two sets of models these galaxies do not seem to have significantly oval discs.

As part of his Ph.D. project, Mitchell developed and released saltfppipe, an open-source data reduction Python package for processing SALT Fabry–Pérot data. This package builds on many other open-source software packages, including the PySALT package maintained by SAAO.

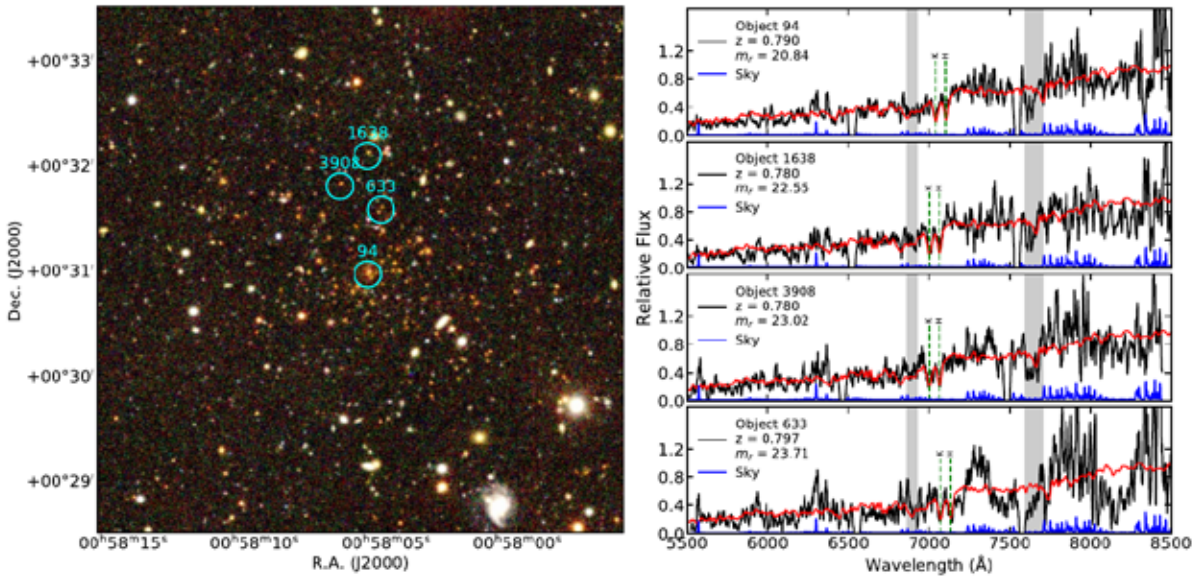


SALT observations and models of NGC 2280. Shown are the median *R*–band surface brightness, continuum surface brightness, Hα surface brightness, N II surface brightness, line-of-sight velocity, velocity uncertainty, DiskFit kinematic model, model residual, and extracted rotation curve.

Mitchell, C.J., et al., 2018/03, AJ 155, 123: The RINGS Survey. III. Medium-resolution Hα Fabry–Pérot Kinematic Data Set

A GALAXY CLUSTER CATALOGUE BASED ON THE SUNYAEV–ZEL'DOVICH EFFECT

The Sunyaev–Zel'dovich (SZ) effect is the inverse Compton scattering of cosmic microwave background photons by the hot gas in galaxy clusters. The size of the SZ signal allows detection of massive clusters throughout the universe, regardless of how far away they are. By measuring the growth of clusters over cosmic time, it is possible to measure cosmological parameters and to infer the amounts of dark matter and energy in the universe. The team around Matt Hilton from the University of KwaZulu–Natal in South Africa has used the Atacama Cosmology Telescope (ACT) to conduct a search for galaxy clusters using this effect. First, they optically confirmed that galaxy clusters were associated with their candidate SZ signal, after which they measured their redshifts. The presented catalogue comprises 182 SZ clusters. Multi-object spectroscopic (MOS) observations with SALT/RSS were used to measure the redshifts of 5 clusters at z ~ 0.8. These are the highest redshift clusters that the group has observed with SALT so far, building on their previous work of measuring dynamical masses of lower redshift clusters with RSS. The pipeline used to reduce the RSS MOS observations is available on github.



Left: 5'×5' false-colour optical image of the z = 0.79 cluster ACT–CL J0058.1+0031. SALT spectra for four galaxies (cyan circles) are shown to the right. Black lines: smoothed SALT/RSS spectra; red lines: best match redshifted SDSS spectral template; blue line: sky spectrum; gray bands: regions strongly affected by absorption features in the atmosphere.

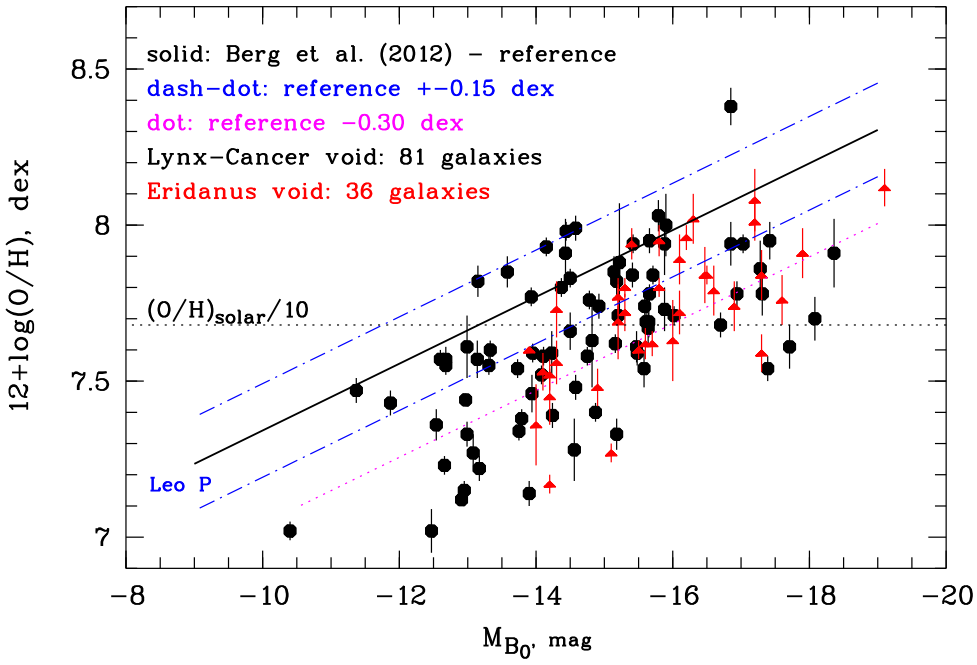
Hilton M., et al., 2018/03, ApJS 235, 20: The Atacama Cosmology Telescope: The Two-season ACTPol Sunyaev–Zel'dovich Effect Selected Cluster Catalog

SALT REVEALS UNDER-ABUNDANT GALAXIES IN THE ERIDANUS VOID

The modern cosmological Λ–CDM models of large-scale structure and galaxy formation predict that galaxy properties and their evolution can significantly depend on the global environment. The role of the most rarefied environment (typical of voids) in galaxy formation and evolution, however, is not well studied either theoretically or observationally.

In particular, most of the mass studies of galaxies in voids, based on large samples from the SDSS spectral database, are limited to rather distant, giant voids (at D ~ 100 – 200 Mpc) and hence probe only the upper part of the void–galaxy luminosity function, namely galaxies with $M_B \leq -16^m$ to $\leq -17^m$. Besides, analyses presented in the literature so far are based on SDSS data precluding the direct study of the evolutionary status of void galaxies. While some differences were found in the global properties of void galaxies with respect to that of the wall population, they are rather modest. Thus one could conclude that for the upper mass/luminosity range the effect of the void environment is rather subtle.

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



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

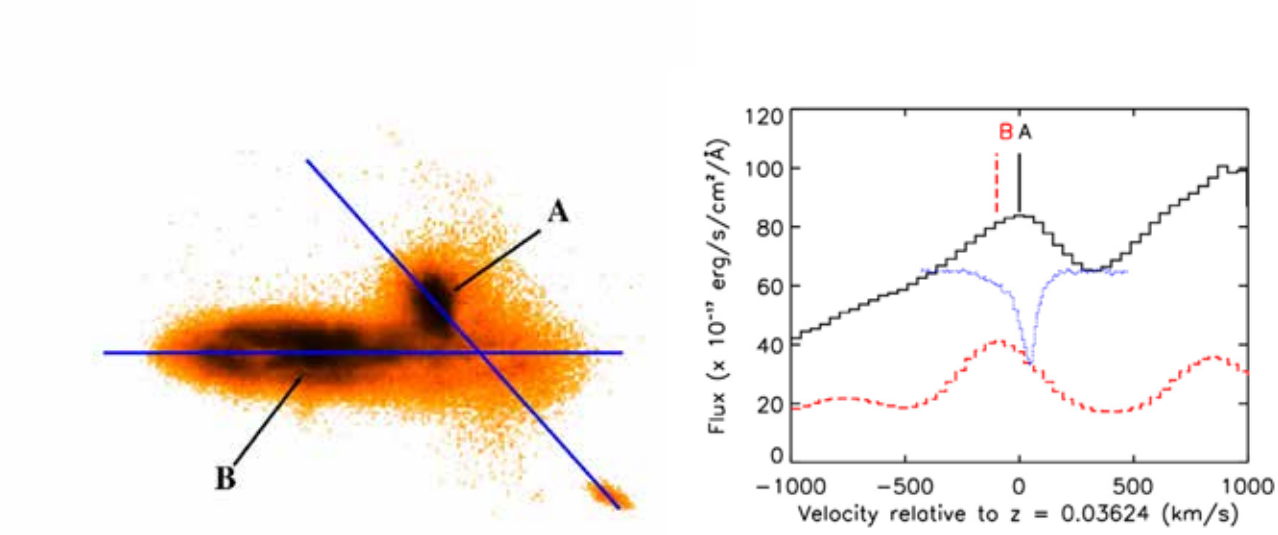
Kniazev, A.Y., Egorova, E.S. and Pustilnik, S.A., 2018/09, MNRAS 479, 3842: Study of galaxies in the Eridanus void. Sample and oxygen abundances

PREVALENCE OF NEUTRAL GAS IN CENTRES OF MERGING GALAXIES

Major galaxy mergers can funnel large quantities of gas to the central regions of galaxies, triggering intense bursts of star formation and fueling active galactic nuclei (AGNs). The connection between galaxy mergers and AGN activity, however, remains debatable, with some studies having found evidence for such a connection for both radio-loud and radio-quiet AGNs, while other studies, using different redshifts, found no such evidence.

To remedy the lack of a sample with good-quality optical imaging as well as spectroscopic data, Rajeshwari Dutta and her colleagues recently carried out a study of the circumnuclear atomic gas in ten radio-loud AGNs that are associated with $z < 0.2$ merging galaxies, using H I 21-cm line absorption observations with the radio telescopes GMRT and VLA. They found statistical evidence for the presence of a large amount of neutral gas (N (H I) ~ 10^{21-22} cm^{-2}) in the central regions (few kpc) of these mergers.

The authors obtained SALT/RSS long-slit optical spectra of four of the mergers. These spectra were used to estimate the redshifts of the galaxies undergoing merger from the nebular emission lines. By comparison with the H I absorption line, the velocity offset of the peak H I optical depth from the systemic redshift could be determined and, notably, whether the H I gas shows blueshifted or redshifted absorption components. They found that the fraction of redshifted absorption components (with respect to the systemic velocity of the radio source) is higher among mergers by a factor of two or three compared to the fraction found for non-interacting systems. In two of the mergers, Dutta and her colleagues were able to carry out spatially-resolved optical spectroscopy over ~ 25 – 35 kpc across the galaxies. They derived various properties from the nebular emission lines, like the star formation rate, metallicity and dust attenuation, and inferred the excitation mechanism to be AGN, based on the emission line ratios and the BPT diagnostic used to classify the emission line region.



Left: SDSS *r*–band image of the merger J1100+1002 showing the RSS slit positions. The strong radio emission is associated with the nucleus of galaxy A.

Right: Zoomed-in view of the Ha emission from the central region of both galaxies. The H I absorption line detected towards the radio source A is shown as a dotted line. The strongest absorption component coincides in velocity with the peak optical emission from nucleus A, indicating a large amount of neutral gas in the circumnuclear region.

Dutta, R., Srianand, R., and Gupta, N., 2018/10, MNRAS 480, 947: Prevalence of neutral gas in centres of merging galaxies

SALT VARIABILITY CAMPAIGN OF THE CHANGING-LOOK AGN HE1136–2304

Active galactic nuclei (AGNs) are variable at all frequencies on time scales of minutes to decades. However, they do not vary regularly and the variability amplitudes are different from object to object. Some Seyfert galaxies, though, exhibit extreme X-ray variations, by a factor of ten and more, in combination with X-ray spectral changes, i.e., when a Compton-thick AGN becomes Compton-thin and vice versa; these are dubbed changing-look AGNs. By analogy, optical changing-look AGNs show transitions from Seyfert type 1 to type 2 and vice versa. Such variations could be caused by a tidal disruption event, by variation in the intrinsic accretion power/nuclear power or by a significant variation in the absorption.

A strong outburst in the X-ray continuum and a change of its Seyfert spectral type has been detected in HE 1136–2304 in 2014. The spectral type changed from nearly Seyfert type 2 to Seyfert type 1.5 in comparison to previous observations taken ten to twenty years before. A research group led by Wolfram Kollatschny from Universität Göttingen carried out a subsequent spectral variability campaign with SALT for the years 2015 to 2017. The researchers wanted to investigate whether the outburst in 2014 was a single event or whether the variability pattern following the outburst was similar to those seen in other variable Seyfert galaxies. In addition to the SALT campaign, they executed X-ray and UV Swift monitoring studies from 2014 to 2017.

HE 1136–2304 strongly varied by a factor of two to eight in the X-rays and in the optical on timescales of days to months from 2014 to 2017. No systematic trends were found in the variability behaviour following the outburst in 2014. Figure 1 shows the optical and X-ray light curves from 2014 to 2016. Rapid variations like the ones depicted cannot be explained by dust variations. A general decrease in flux as expected for a tidal disruption event could not be confirmed. The flux variations are thus more likely connected to irregular fluctuations in the accretion rate. The spectral type of HE 1136–2304 remained as Seyfert type 1.5 between 2014 and 2017 despite its strong continuum variations at the same time (see Figure 2).

In 2015, Kollatschny and his collaborators used SALT to carry out a detailed variability study of the integrated as well as spatially resolved line profiles of HE 1136–2304. They found that the broad line region (BLR) is stratified with respect to the distance of the line-emitting regions. The integrated emission lines of Hα, Hβ, He I λ5876, and He II λ4686 originate at distances of 15.0, 7.5, 7.3, and 3.0 light-days with respect to the optical continuum at 4570 Å. Figure 3 shows the cross-correlation functions (CCFs) of the variable integrated Balmer and helium lines with respect to the variable optical continuum. Based on the distances of these line-emitting regions and on the line-widths of the individual emission lines, the central black hole mass is 3.8 x 10^7 Solar masses.

Variations of the line profiles contain information about the geometry and kinematics in the BLR. One can make additional statements about inflow, outflow or Keplerian motions in the BLR when comparing the observed velocity-delay pattern of the emission lines with model calculations. The authors sliced the observed emission line profiles in HE 1136–2304 into velocity bins and correlated all their individual light curves with the continuum light curve. Figure 4 shows the 2D CCF of the Hβ line-segment light curves with the continuum light curve as a function of velocity and time delay. The outer line wings of Hβ and of all the other BLR lines respond much faster to continuum variations than the central line regions, indicating a Keplerian disc geometry for the BLR in HE 1136–2304.

Otherwise, the variability behaviour of this changing-look AGN is similar to that of other AGNs.

Zetzl, M., et al., 2018/10, A&A 618, A83: Long-term optical, UV, and X-ray continuum variations in the changing-look AGN HE 1136–2304
Kollatschny, W., et al., 2018/11, A&A 619, A168: Broad-line region structure and line profile variations in the changing look AGN HE 1136–2304

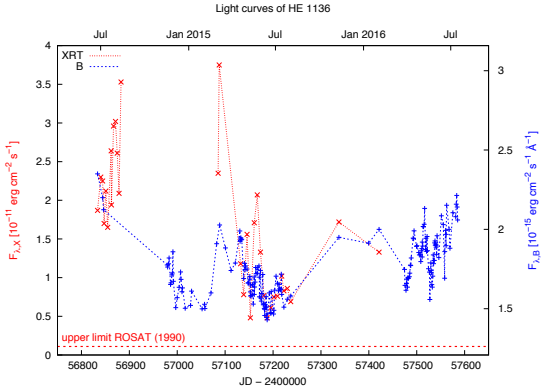


Fig 1: Optical (blue) and X-ray (red) light curve from 2014 to 2016. The upper limit of the X-ray flux in 1990 (ROSAT) is shown by a horizontal dashed line.

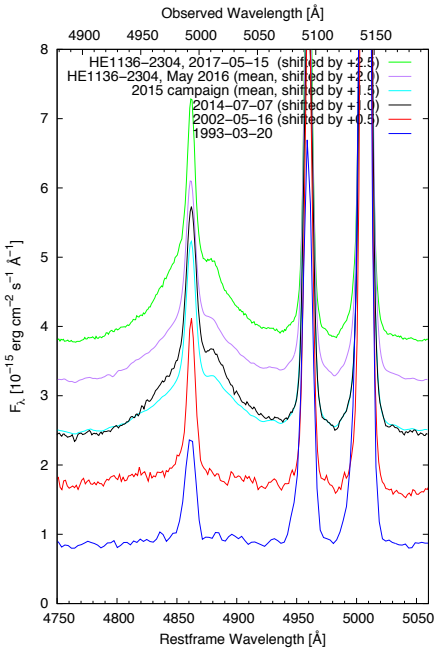


Fig 2: Optical spectra of HE 1136–2304 for the years 1993 to 2017 showing the Hβ profiles in detail.

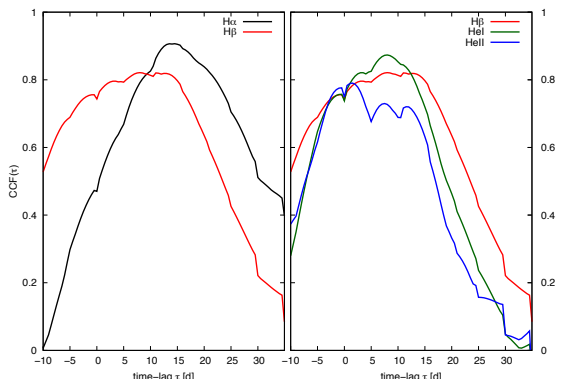


Fig 3: CCFs of the integrated Hα, Hβ, He I λ5876, and He II λ4686 lines with respect to the continuum at 4570 Å.

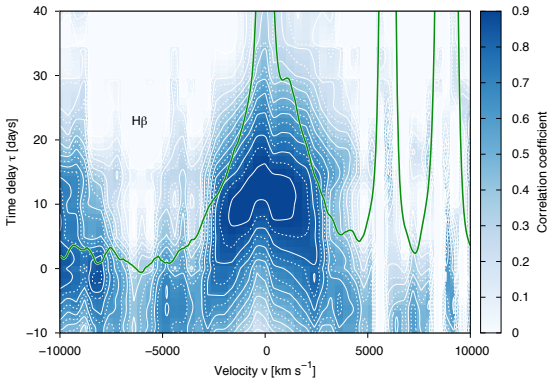


Fig 4: 2D CCF(τ,v) showing the correlation coefficient of the Hβ line-segment light curves with the continuum light curve as a function of velocity and time–delay (blue scale). Contours of the correlation coefficients are plotted at levels 0.0 to 0.9 every 0.05 (white lines). The green line shows the line profile of the mean spectrum.

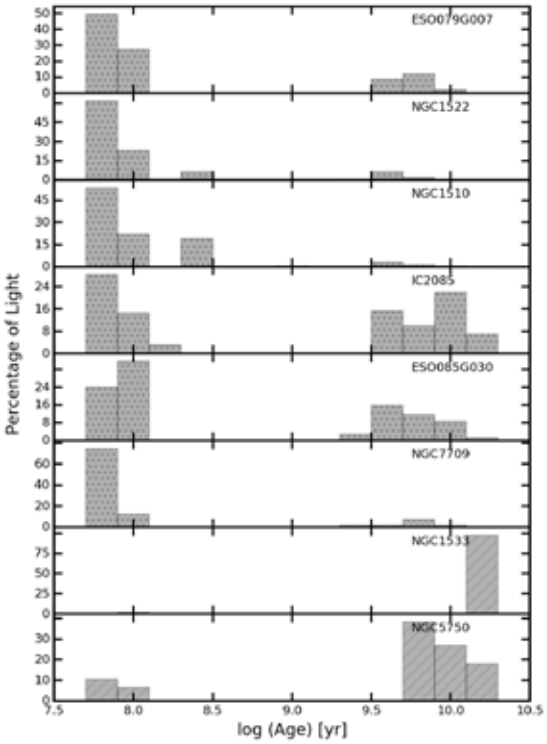
A SALT SPECTRAL STUDY OF S0'S HOSTING PSEUDO BULGES

S0 or lenticular galaxies are characterised by the presence of an elliptical-like bulge and a smooth outer disc devoid of any apparent spiral arms. While the bulges are assumed to be likely formed in a similar manner to elliptical galaxies, i.e., through hierarchical clustering and mergers, the observation that the fraction of S0 galaxies within a cluster of galaxies grows at the cost of spiral galaxies suggests that S0s originate from spirals. Gas stripping via ram pressure is often considered a viable process for such a transformation in dense cluster environments, but S0s are equally common in galaxy groups. A possible solution is that the dominant formation process of S0s is a function of luminosity, with brighter S0s forming in a manner similar to ellipticals and fainter S0s forming through secular processes or perhaps by gas stripping of spirals. The latter are assumed to have pseudo bulges, that is, bulges resembling discs.

Through application of their expertise in 2D surface brightness profiling, Ph.D. student Kaustubh Vaghmare at IUCAA and colleagues have previously argued that S0s hosting pseudo bulges are consistent with their being gas-stripped spirals. In other words, these S0s were once spirals and underwent processes which led to a loss of gas, the fading of the spiral arms and a transformation into their current morphology as S0 type.

As part of his project, Vaghmare used longslit spectra obtained with SALT/RSS to study 8 of the 25 pseudo-bulge-hosting S0s which the team had studied previously. He used the STARLIGHT program, the MILES spectral library and sophisticated techniques such as diffusion mapping to model the spectra and derive detailed star formation histories for these galaxies. For the six unbarred galaxies he finds evidence of strong ongoing star formation and a dominant young, recently-formed population of stars. While the latter finding is consistent with their hosting a pseudo bulge, the observation of ongoing star formation is in contradiction with the argument that these are gas-stripped spirals. This seems to suggest an overall inefficiency of the stripping mechanisms in removal of gas from the central regions of the galaxy.

The other two galaxies, which are barred, exhibit a very old stellar population. This suggests that the funneling action of the bar has led to an accelerated growth of the pseudo bulge. One of these galaxies has depleted its reservoir of gas and shows no sign of ongoing star formation, while the other galaxy has managed to form a relatively new population of stars. The conclusion regarding the influence of a bar on the stellar population, however, is not robust owing to the small number of galaxies involved. Vaghmare and his colleagues thus used the $D_n(4000)$ index (ratio of the integrated fluxes at 4000 – 4100 Å and at 3850 – 3950 Å) as a proxy for age and show, using a sample of SDSS galaxies, that barred, pseudo-bulge-hosting galaxies have in fact preferentially older stellar populations than was found for the small SALT sample.



Star formation histories for the sample galaxies. The x-axis indicates the logarithm of the age and the y-axis the percentage of light contributed to the observed spectrum by a stellar population of the given age. These percentages are computed from the population vector returned by starlight. The top six galaxies are unbarred and the last two galaxies are barred.

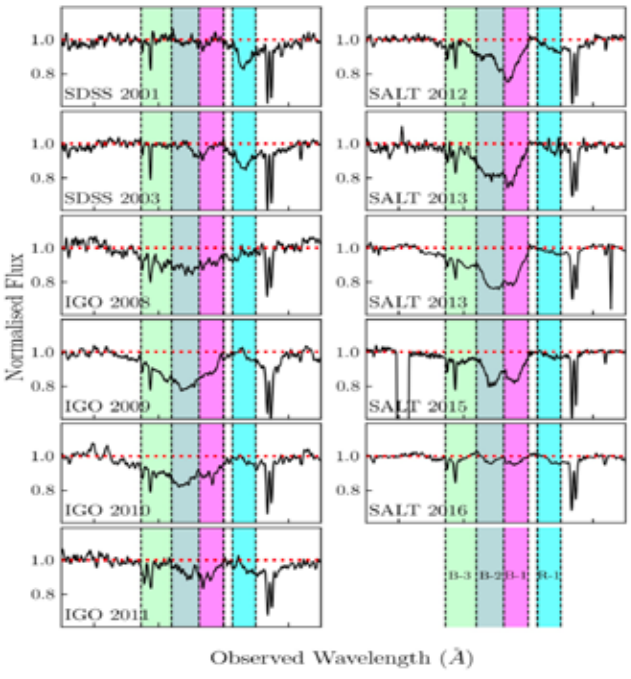
Vaghmare, K., et al., 2018/11, MNRAS 480, 4931: A SALT spectral study of S0s hosting pseudobulges

SDSS 1333+0012: A QUASAR CONTAINING A DRAMATICALLY VARIABLE MG II BROAD ABSORPTION LINE TROUGH

Despite the increase in the number of known quasars, the detailed physics of quasar outflows is still uncertain. Absorption line variability studies of broad absorption lines (BAL) are an essential tool for understanding the gas dynamics occurring close to the quasar's central engine. SDSS J1333+0012, at a redshift of 0.92, shows rapid variations in its high-velocity Mg II BAL trough. In a previous work, this quasar was reported to contain a BAL trough which appeared and disappeared over a timescale of 2 years in the quasar rest-frame. In 2012, Vivek and Srianand from the Inter–University Centre for Astronomy and Astrophysics in Pune, India, decided to follow up this interesting source using SALT's RSS to monitor the variable Mg II BAL.

The spectra obtained over 5 years (2012 – 2017) reveal that the Mg II BAL trough continues to show dramatic variability: nearly disappeared, the high-velocity BAL trough from 2011 re-appeared in the SALT 2012 spectrum. Furthermore, the BAL trough increased its depth and reached a maximum in 2014. Afterwards, the BAL trough decreased its strength and nearly disappeared again in 2016. On the contrary, the quasar continuum light does not show strong variability correlated with the absorption line variability, as would be expected in a simple photo-ionisation scenario.

Using photo-ionisation simulations, the authors argue that the observed variations of the blue-component BAL trough can be explained by variable photo-ionisation conditions of the outflow regulated by `shielding gas' located at the base of the outflow. As required, the *V*–band continuum of the quasar is not sensitive to changes introduced by such shielding gas. However, the variable shielding gas scenario cannot explain the disappearance of the red component that never re-appeared during the SALT monitoring period. The observed absorption line variability could also be explained by multiple streaming gas clouds moving across the line of sight, but there are some inconsistencies with this scenario, too. It is thus most likely that the actual scenario may be a combination of variable shielding gas and multiple streaming gas clouds.



Comparison of the normalised spectra at all epochs. The wavelength regions of the three blue components and the red component are shaded in green, grey, blue, and cyan, respectively. In each panel, the telescope and year of the observations is given at the lower left.

Vivek, M., Srianand, R., and Dawson, K.S., 2018/12, MNRAS 481, 5570: Rapidly varying Mg II broad absorption line in SDSS J133356.02+001229.1

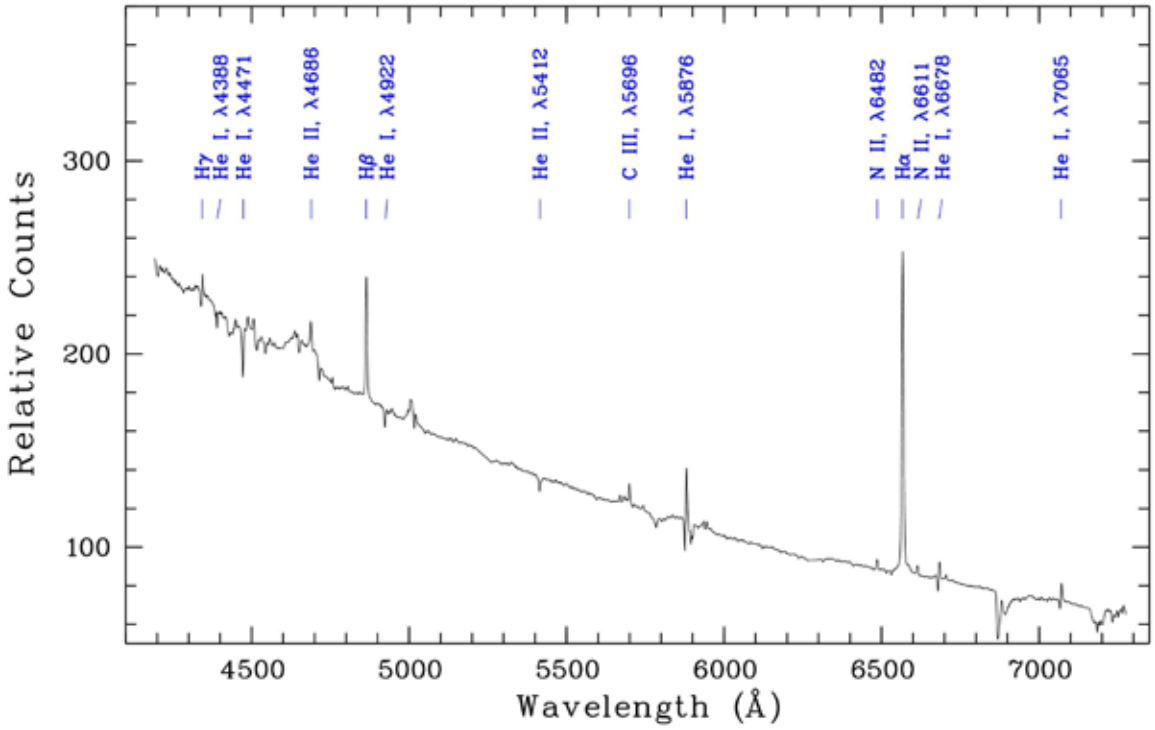
Stellar and Galactic astronomy

34
SCIENCE
HIGHLIGHTS

THE BLUE SUPERGIANT SK–69° 279 AND ITS CIRCUMSTELLAR SHELL

Mass-loss from massive stars usually results in the formation of compact (parsec-scale) circumstellar nebulae of various morphologies. Among the massive stars, compact circumstellar nebulae are most often found around luminous blue variables (LBVs), that is, observations show that about 60 percent of known bona fide and candidate LBVs are surrounded by such nebulae. Thus, the presence of compact nebulae around hot, luminous stars could be used to find ex-/dormant LBVs, even if they currently do not show significant spectroscopic and photometric variability. On the other hand, it is still not fully clear at what point(s) in the evolution the massive stars become LBVs and produce their nebulae. Although it is likely that many LBVs are at advanced stages of stellar evolution, there are observational hints that the LBV phenomenon might also be related to stars that only recently left the main sequence or are even still on it, and that the LBV-like nebulae might be ejected before the underlying stars become LBVs.

Vasilii Gvaramadze from the Sternberg Astronomical Institute in Moscow as well as Alexei Kniazev from SAAO and other collaborators have used RSS on SALT to obtain optical spectroscopy of the blue supergiant Sk–69° 279 and its circular shell in the Large Magellanic Cloud. The spectrum shows that surface helium and nitrogen abundances of this O9.2 Iaf star are enhanced by factors of about 2 and 2030, respectively, and that the shell is composed mostly of the CNO-processed material lost by the star. These findings suggest that either Sk–69° 279 was initially a (single) fast-rotating (about 400 km/s) star which only recently evolved off the main sequence, or that it is a product of close binary evolution. This supports the proposition that some massive stars can produce compact circumstellar shells and presumably appear as LBVs while they are still on the main sequence or have recently left it.



The fully reduced RSS spectrum of Sk–69° 279 with the most prominent lines indicated.

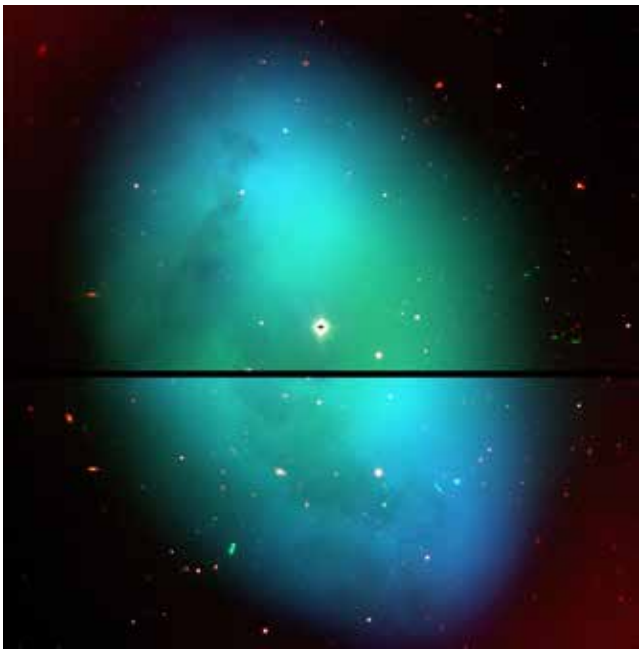
Gvaramadze, V.V., et al., 2018/02, MNRAS 474, 1412: Optical spectroscopy of the blue supergiant Sk–69° 279 and its circumstellar shell with SALT

SALT DISCOVERS LONG-PERIOD BINARY CENTRAL STARS IN THE PLANETARY NEBULAE NGC 1360 AND MYCN 18

In the last decade, astronomers have discovered several new examples of planetary nebulae (PNe) that host binary central stars. To date, almost 50 are known, with most binaries having orbital periods of about one day or less. These binaries indicate that the PNe formed via a common-envelope (CE) interaction, a critically important phase of binary stellar evolution that is poorly understood. The PNe offer a unique window into the immediate aftermath of this interaction where the nebula itself is thought to be the ejected common-envelope. While at least one in five PNe have a close binary nucleus, it is suspected that many more PNe are shaped by binary interactions because of their unusual nebula shapes.

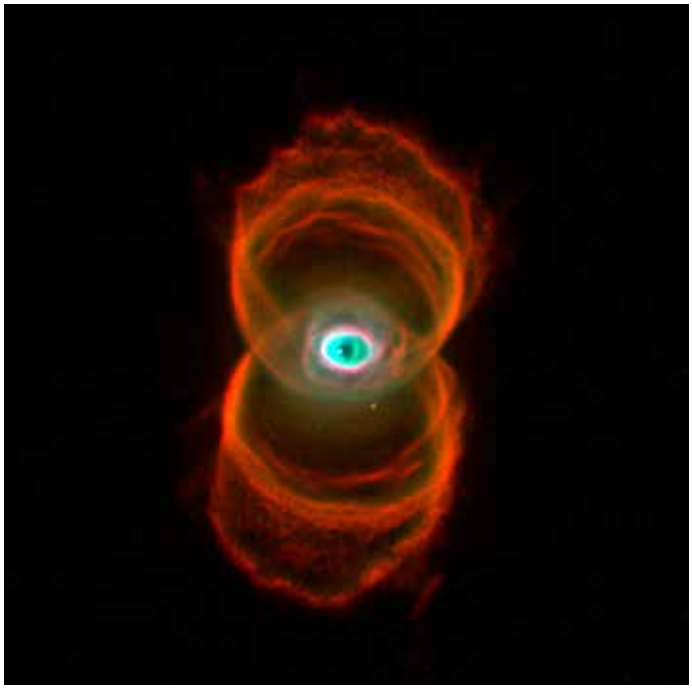
Orbital studies of other post-AGB binaries frequently find orbital periods of a few hundred to several thousand days. If a large fraction of PNe are shaped by binaries, we would expect a substantial population of PNe to exhibit similar orbital periods. However, apart from three binary central stars of PNe with orbital periods in excess of 1100 d, discovered by the HERMES facility on the Flemish Mercator telescope on La Palma, the next longest orbital period is only 16 d (NGC 2346). Brent Miszalski and his colleagues have thus commenced a still ongoing, systematic survey for long-period binary central stars with SALT/HRS to search for this missing population. The stability and high resolution of SALT/HRS is ideally suited to detect the expected small radial velocity amplitudes of 10 km/s or less. The first two published discoveries from this program are NGC 1360 and MyCn 18.

NGC 1360 (PN G220.3–53.9) is a relatively large PN with a bright central star (V = 11.3 mag). The central star was previously thought to have a kilogauss magnetic field, which could have potentially influenced the nebula shape, but this detection has since been disproven. The SALT/HRS observations reveal an orbital period of 142 d and a radial velocity semi-amplitude of only 11.8 km/s. The companion most consistent with the observations is an evolved white dwarf, making NGC 1360 the longest orbital period double-degenerate binary known. Analysis of archival ESO's VLT–FORS2 images reveals a new ring of low-ionisation filaments surrounding the central star. This feature is often found in other post-CE PNe (e.g., The Necklace) and is attributed to photo-ionisation of material deposited in the orbital plane during the CE interaction. The binary nucleus may therefore be one of the longest orbital period post-CE binaries. More recent SALT/HRS observations are consistent with the published orbital solution. *Continues on page 37*

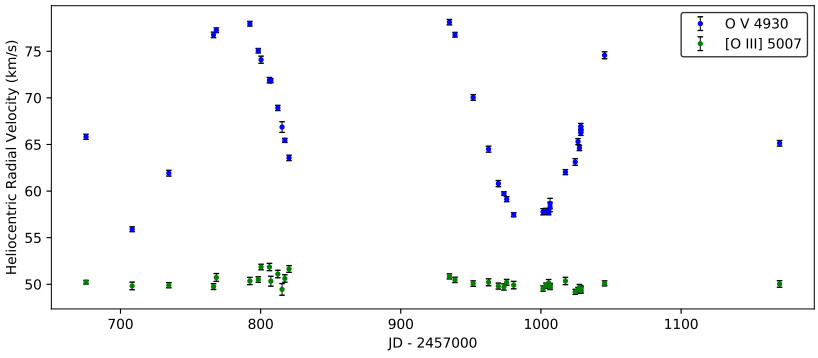


ESO VLT–FORS2 colour-composite image of NGC 1360 made from images taken with *I*–band (red), Hα+N II (green) and O III (blue) filters.

MyCn 18 (PN G307.5–04.9) is a young PN that is remarkable for its breathtaking Hubble Space Telescope images and for its likeness to the nebular remnant of SN 1987A. The faint central star (V = 14.9 mag) appears offset from the geometric centre of the hourglass-shaped nebula, giving the uncanny appearance of an eye. Outside the main nebula is a pair of jets travelling at up to 630 km/s, the fastest observed amongst PNe. MyCn18 has long been suspected of hosting a binary nucleus, inspiring several widely-accepted binary-driven formation scenarios for various morphological features of PNe. The SALT/HRS observations find an orbital period of 18.15 d and a radial velocity semi-amplitude of only 11.0 km/s, implying that the companion is an M dwarf. The companion and orbital period are not sufficient to produce a classical nova, previously suspected to be the source of the observed high jet velocities. The 18.15-day orbital period is significantly shorter than expected by the afore-mentioned formation scenarios and indicates that CE evolution is instead the dominant influence on the morphology of MyCn 18. The binary nature of MyCn 18 brings us closer to understanding the elusive origins of bipolar nebulae across different classes of binary stars. The strong similarities with the nebular remnant of SN 1987A (the product of a massive binary CE merger) suggest that the CE interaction appears to be a strong determining factor in producing bipolar morphologies.



HST colour-composite image of MyCn 18. Image credit: Raghvendra Sahai and John Trauger (JPL), the WFPC2 science team, and NASA.



SALT/HRS radial velocity measurements of the central star of NGC 1360 using the O V λ4930 stellar emission line (blue). The radial velocity of the nebular O III λ5007 emission line is shown for comparison (green). Note the clear 142 d periodic variability in the central star due to orbital motion.

Miszalski, B., et al., 2018/01, MNRAS 473, 2275: SALT HRS discovery of a long-period double-degenerate binary in the planetary nebula NGC 1360

Miszalski, B., et al., 2018/02, MNRAS 474, 646: Erratum: SALT HRS discovery of a long-period double-degenerate binary in the planetary nebula NGC 1360

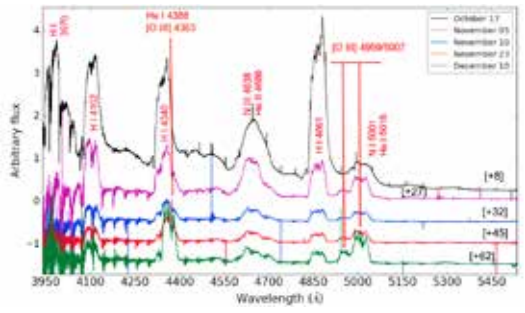
Miszalski, B., et al., 2018/06, PASA 35, 27: SALT HRS Discovery of the Binary Nucleus of the Etched Hourglass Nebula MyCn 18

STUDYING NOVAE WITH SALT

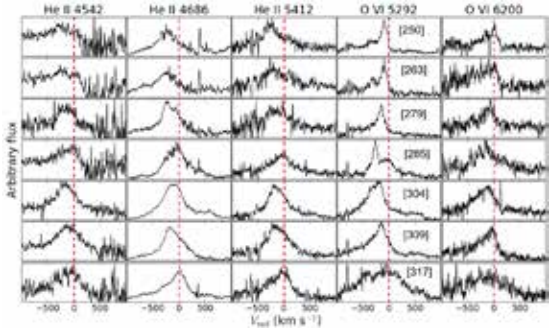
With the ability to respond rapidly to targets of opportunity and its high-resolution optical spectroscopic capability, SALT is a powerful machine for studying classical novae, that is, stellar eruptions occurring on the surface of a white dwarf star in an interacting binary system. In the last two years more than 10 classical novae were observed under the SALT Large Science Programme for transients, led by David Buckley from SAAO, with the aim to combine these observations with multi-wavelength studies to improve the understanding of this class of transient objects. Ph.D. student Elias Aydi from SAAO has studied in detail the cases of novae SMCN 2016–10a and V407 Lup.

SMCN 2016–10a — one of the brightest novae ever observed. MCN 2016–10a is a classical nova eruption that was discovered in October 2016, located in the direction of the Small Magellanic Cloud (SMC). The optical brightness of the eruption was found to be record breaking: assuming a distance of the SMC, the nova would not only be the brightest observed in the Cloud, but one of the brightest novae ever. The optical light-curve of SMCN 2016–10a reached a maximum V–magnitude of ~ 8.5 mag and, assuming the distance of the SMC, an absolute maximum magnitude of ~ –10.5 mag. The SALT/HRS was used to follow up on the nova throughout the different stages of the eruption, which helped constrain the velocities of the ejected matter, its chemical composition and the morphology.

V407 Lupi — a very fast nova erupting in an intermediate polar. V407 Lup (ASASSN–16kt) is a classical nova eruption which occurred in September 2016 in the constellation of Lupus. Timing analysis of the multi-wavelength light curves shows that from day 168 post-eruption to the end of the X-ray supersoft source phase, two periods at 565 s and 3.57 h were detected. Aydi and his collaborators suggest that these are the rotational period of the white dwarf and the orbital period of the binary, respectively, and that the system is likely to be an intermediate polar (a cataclysmic variable system with a highly magnetised and rapidly rotating white dwarf). The SALT optical spectroscopic monitoring data taken during this time show the emergence of relatively narrow and moving He II and O VI emission lines. These are spectral characteristics of magnetic cataclysmic variables and typically originate from hot regions around the white dwarf and from the accretion disc. The multi-wavelength dataset favours the possibility that the accretion resumed soon after the eruption, while the X-ray supersoft source phase was still lasting, possibly extending its duration.



SALT/HRS spectra of SMCN 2016–10a with the flux in arbitrary units. For clarity the spectra are shifted vertically. The numbers in brackets are days since discovery.



The evolution of the profiles of the 'moderately narrow' emission lines (labelled at the top) of V407 Lup. A heliocentric correction was applied to the radial velocities. The flux is in arbitrary units. The numbers in brackets are days since discovery. The red dashed lines represent the rest-wavelength of each line (v_{rad} = 0 km/s).

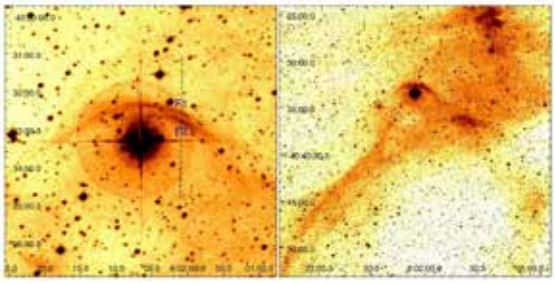
Aydi, E., et al., 2018/02, MNRAS 474, 2679: Multiwavelength observations of nova SMCN 2016–10a − one of the brightest novae ever observed

Aydi, E., et al., 2018/10, MNRAS 480, 572: Multiwavelength observations of V407 Lupi (ASASSN–16kt) − a very fast nova erupting in an intermediate polar

INTERSTELLAR STRUCTURES AROUND THE RUNAWAY HIGH-MASS X-RAY BINARY VELA X–1

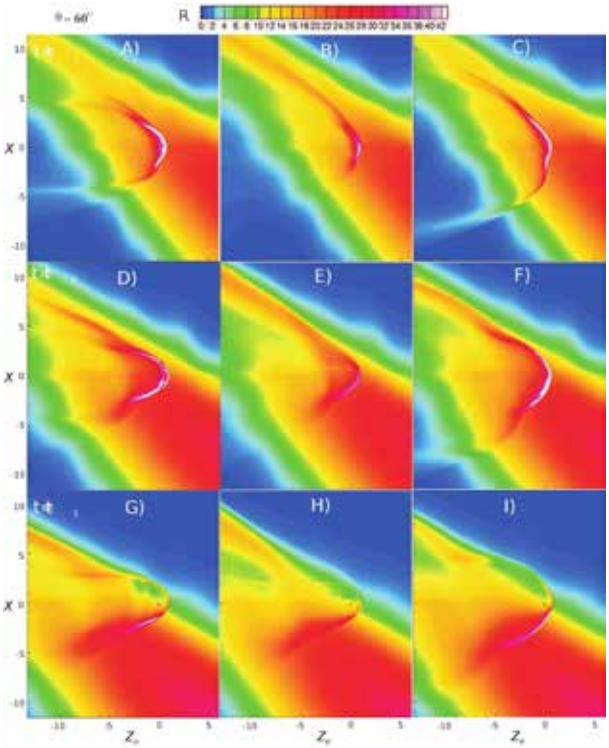
Wind-blowing stars moving supersonically through the interstellar medium (ISM) generate bow shocks in the upwind direction. These so-called runaway stars move through the Galactic disc and interact with density inhomogeneities on their way. Signatures of this interaction might persist for a long time behind the runaway stars in the form of elongated bubbles or wakes of shocked gas. The geometry of these is defined by the density distribution in the local ISM, the stellar mass-loss history and instabilities at the wind/ISM interface.

Vasilii Gvaramadze and his Russian–South African team discovered filamentary structures stretching behind the bow-shock-producing high-mass X-ray binary (HMXB) Vela X–1, using the SuperCOSMOS Hα Survey. SALT/RSS spectroscopy of the bow shock allowed them to determine the reddening and number density of the local ISM towards Vela X–1. Gaia DR1 data and published heliocentric radial velocity measurements were used to calculate the 3D-space velocity of this HMXB, indicating that Vela X–1 is approaching us with a velocity of about 30 km/s and that the vector of its space velocity is inclined to our line of sight by an angle of about 60°.



SuperCOSMOS Hα images of the bow shock generated by the HMXB Vela X–1 (left) and a 30'× 30' field containing Vela X–1 and the filamentary structures behind it (right). The arrow and dashed line (left) show, respectively, the direction of motion of Vela X–1 and the orientation of the SALT spectrograph slit. Assuming a distance of 2 kpc, 1 arcminute corresponds to 0.57 pc.

The geometry of the detected filamentary structures suggests that Vela X–1 has encountered a wedge-like layer of enhanced density on its way and that the shocked material of this layer partially outlines a wake downstream of Vela X–1. To substantiate this suggestion, the authors carried out 3D magnetohydrodynamic simulations of the interaction between Vela X–1 and the encountered layer for three limiting cases: the stellar wind and the ISM were treated as pure hydrodynamic flows (model 1); a homogeneous magnetic field was added to the ISM, while the stellar wind was assumed to be unmagnetised (model 2); the stellar wind was assumed to possess a helical magnetic field (described by the Parker solution), while there was no magnetic field in the ISM (model 3). It was found that although the first two simulations can provide a rough agreement with the observations, only the third one reproduced the wake behind Vela X–1, as well as the general geometry of the bow shock ahead of it.

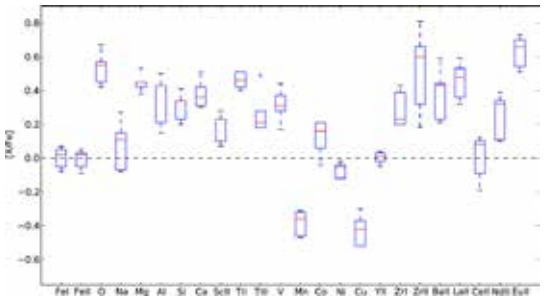


Projection of synthetic Hα intensity maps with a line of sight at an angle of 60° to the symmetry axes of the models 1, 2, and 3 (left to right) at three times (top to bottom).

Gvaramadze, V.V., et al., 2018/03, MNRAS 474, 4421: Modelling interstellar structures around Vela X–1

HIGH-RESOLUTION SPECTROSCOPIC ABUNDANCES OF RED GIANT BRANCH STARS IN NGC 6584 AND NGC 7099

Erin O'Malley and Brian Chaboyer from Dartmouth College, together with Alexei Kniazev from SALT/SAAO, used SALT/HRS to obtain high resolution (R ~70,000), high signal-to-noise (S/N ~100) spectra of 10 red giant branch (RGB) stars in the globular clusters NGC 6584 and NGC 7099. These spectra were used to perform a detailed abundance analysis of the stars in each cluster. The team confirmed cluster membership for these stars based on consistent radial velocities measured in their study and on photometric considerations. Mean metallicities of [Fe/H] = –1.53 ± 0.08 dex and [Fe/H] = –2.29 ± 0.07 dex were found for NGC 6584 and NGC 7099, respectively. These clusters are enhanced in their [α/Fe] ratios, consistent with what is expected for metal-poor globular clusters. There is a statistically significant Na–O anti-correlation in both clusters, similar to that found in other globular clusters. The relative contribution of the slow (s-process) and rapid (r-process) neutron capture nucleosynthesis in building up the heavy element content in the two clusters was studied by examining the europium (primarily produced by the r-process) and barium (primarily produced by the s-process) abundances. The observed [Ba/Eu] abundances indicate that the heavy elements in NGC 6584 and NGC 7099 were primarily created by the r-process, though there was a significant contribution from the s-process.

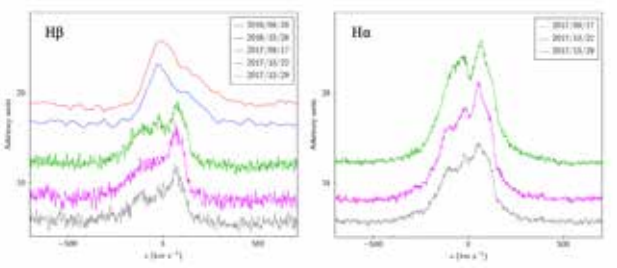


Abundance pattern for the sample of RGB stars in NGC 6584. The boxes represent the inter-quartile range (i.e., the middle 50% of the sample), while the red horizontal line in each box denotes the median value. Outliers beyond 1.5 times the second and third quartile are indicated as blue crosses.

O'Malley, E. M. and Chaboyer, B., 2018/04, ApJ 856, 130: High-resolution Spectroscopic Abundances of Red Giant Branch Stars in NGC 6584 and NGC 7099

SALT IDENTIFIES SUPERSOFT X-RAY SOURCES AS BE BINARIES

Some luminous supersoft X-ray sources are associated with massive stars, proposed to be Be-type stars. Valentina Cracco from the University of Padova in Italy, in close collaboration with Marina Orio and others from the University of Wisconsin, Padova and SAAO/SALT, used SALT/RSS and HRS to observe the optical counterparts of four luminous supersoft X-ray sources in the Magellanic Clouds: Suzaku J0105–72, XMMU J010147.5–715550, MAXI J0158–744, and XMMU J052016.0–692505. The latter two were confirmed to be Be stars, while the former two show steep blue continua and Balmer hydrogen emission lines typically observed in Be stars. All were confirmed to be members of the Magellanic clouds. The higher resolution spectra show emission lines with double-peaked profiles caused by the presence of an excretion disc, a common property of Be stars. These profiles are variable on shorter time-scales than in isolated Be stars, proving the hypothesis that these sources are binaries, where the companion is a massive white dwarf responsible for the truncation of the disc through tidal interaction and sporadic ignition of nuclear burning that explains the observed supersoft X-ray flares.



Hβ (left) and Hα (right) emission line profiles for XMMU J052016.0–692505, obtained at different epochs with RSS (blue and red lines) and HRS (green, pink and gray lines). Both emission lines show a clear evolution in their profiles.

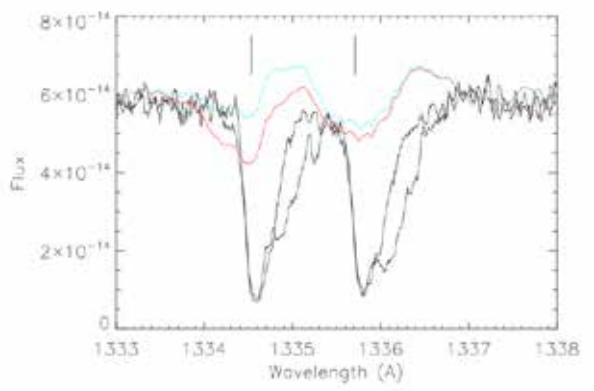
Cracco, V., et al., 2018/08, ApJ 862, 167: Supersoft X-Ray Sources Identified with Be Binaries in the Magellanic Clouds

STAR-GRAZING BODIES IN OTHER SOLAR SYSTEMS

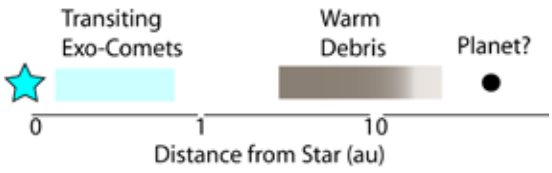
The young stellar system β Pictoris has a large, two-belt debris disc which is viewed edge-on to our line of sight. A distinctive feature of this system is a complex absorption spectrum consisting of absorption in CO and a selection of atomic ions. These features are augmented by variable, redshifted absorption extending up to +400 km/s. Similar absorption is seen in 49 Cet, another, young stellar system. β Pic is the eponymous object in a moving group which has been dated at 24 ± 3 Myr. One of the stars in the moving group, HD 172555, also has a nearly edge-on disc, seen in thermal emission and scattered light. It has been reported in the literature that certain transient absorption features in this system could be associated with star-grazing, transiting exo-comets.

Carol Grady and her collaborators decided to follow up on this and observed HD 172555 with the HST Imaging Spectrograph and Cosmic Origins Spectrograph as well as with SALT/HRS at 2 epochs, separated by a week. They report the discovery of infalling gas in resonant transitions of Si III and IV, C II and IV, and neutral atomic oxygen. Variable high-velocity absorption is seen in the C II transitions, similar to features seen in β Pic. The authors conclude that this absorption is optically thick, with a covering factor for the star-grazing material ranging between 58% and 68% (star not fully obscured). The Ca II profiles obtained with SALT/RSS are much weaker than the HST-detected lines and can be traced only to 10 – 12 km/s, indicating that the infalling material is dominated by volatile species. The O I spectral profile resembles that of C II, showing a strong low-velocity absorption to +50 km/s in the single spectral segment obtained during orbital night, as well as what may be higher velocity absorption.

Models for β Pic and similar objects are based on our Solar system where bodies are perturbed into Sun-grazing orbits by Jupiter. A planet was predicted for β Pic using this model a decade prior to its direct-imaging discovery. For two-belt systems like β Pic and 49 Cet, an open question has been whether the star-grazing bodies originate in the outer or inner debris belt and are analogs of Kuiper Belt objects or asteroids, respectively. For HD 172555, Herschel Space Observatory FIR data indicate a warm debris belt, but no cold debris, indicating that the high-velocity material comes from an analog to the asteroid belt. The presented data indicate nevertheless that the star-grazing bodies in this system contain volatile elements, presumably stored as ices until they approach their star.



C II in HD 172555, as seen by HST. Black: observed spectra; red: the comparison object α Cep; blue: corrected α Cep spectrum.

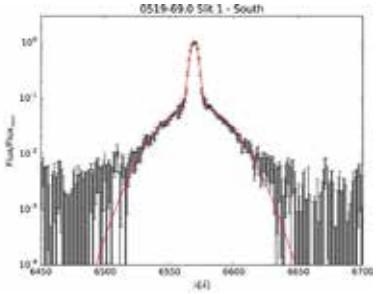


Cartoon of the HD 172555 system. The infalling material is seen interior to 0.5 AU, while near- and mid-IR imagery indicates that warm debris can be traced to ~20 AU. A planet responsible for perturbing bodies from the warm debris belt is inferred to be present, but has yet to be detected. Analysis of data from the Herschel Space Observatory indicates that this system lacks a Kuiper Belt analog.

Grady, C.A., et al., 2018/06, AJ 155, 242: The Star-grazing Bodies in the HD 172555 System

COSMIC-RAY ACCELERATION EFFICIENCY IN BALMER SHOCKS OF SUPERNOVA REMNANTS IN THE LMC

Shocks in supernova remnants (SNRs) seem to be responsible for the acceleration of the bulk of galactic cosmic rays. Luke Hovey (Los Alamos National Lab), Jack Hughes (Rutgers University) and colleagues used SALT/RSS to measure the broad widths of the Hα line in several Balmer-dominated filaments of a supernova remnant (SNR 0519–69.0) in the Large Magellanic Cloud (LMC). In Balmer-dominated filaments like those targeted, the Hα line shows two components: one narrow (unresolved in these observations) and one broad. The measured broad-line widths in the filaments sampled in SNR 0519–69.0 vary between 1800 km/s and 2800 km/s. These widths constrain the temperature of the post-shock protons. The study also used the HST Advanced Camera for Surveys (ACS) images taken at two different epochs to measure the proper motions of the filaments. The well-determined distance to the LMC allowed them to convert the proper motions into accurate shock velocities. The measured broad-line widths were shown to be consistent with the measured shock velocities for the simplest model where the shock energy is predominantly partitioned into a thermal component as well as bulk motion. In particular it was possible to exclude a model where a significant amount of shock energy was diverted as well into a population of relativistic particles (i.e., cosmic rays) accelerated at the shock front. This work indicates that Balmer-dominated shocks are not as efficient particle accelerators as other shocks in young supernova remnants like Tycho and SN1006, adding a new mystery to the search for the source of cosmic rays.

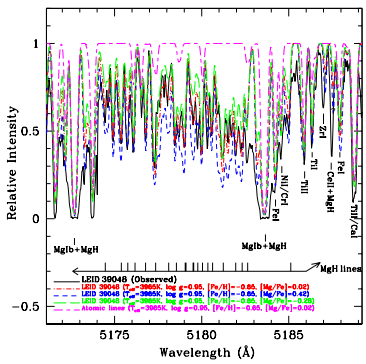


Example of SALT/RSS spectra of the Hα line from one of the two long-slit positions of SNR 0519–69.0. The best-fit spectrum is shown with a red curve.

Hovey, L., et al., 2018/08, ApJ 862, 148: Constraints on Cosmic-ray Acceleration Efficiency in Balmer Shocks of Two Young Type Ia Supernova Remnants in the Large Magellanic Cloud

RELATIVELY HYDROGEN-POOR AND METAL-RICH GIANTS IN ω CENTAURI

Metal-rich giants that are hydrogen-poor and helium-rich provide an important link to the evolution of the metal-rich sub-population of the globular cluster ω Cen. High-resolution optical spectra obtained with SALT/HRS were analysed for two metal-rich and mildly hydrogen-poor but helium-enhanced giants (discovered previously by the authors) along with two normal (hydrogen-rich) giants for comparison. The strengths of the MgH bands were analysed for their derived stellar parameters. The authors found that the spectra of the two hydrogen-poor stars show weaker MgH bands, unlike the spectra of the two normal, comparison giants. The magnesium abundance of the former two, derived by synthesizing the spectra of MgH bands, is less by 0.3 dex or more as compared to the abundance derived from Mg I lines. This difference cannot be reconciled by varying the stellar parameters within their uncertainties. The authors thus attribute the difference to a hydrogen deficiency and helium enhancement in the atmospheres and point out that these measurements are the first direct spectroscopic evidence for the presence of the helium enhancement in the metal rich giants of ω Cen.



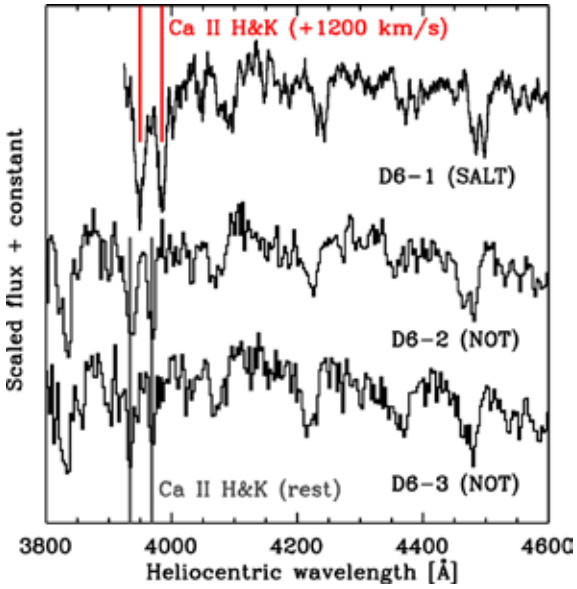
Superposition of the observed and the synthesised spectra for the sample star LEID 39048. The spectrum is synthesised for the star's derived stellar parameters and the Mg abundance. The synthesis is shown for [Mg/Fe] as derived from the MgH line (red) and from the Mg I line (blue), for a comparison [Mg/Fe] (green) and for pure atomic lines (magenta).

Hema, B.P., Pandey, G. and Srianand, R., 2018/09, ApJ 864, 121: High-resolution Spectroscopy of the Relatively Hydrogen-poor Metal-rich Giants in the Globular Cluster ω Centauri

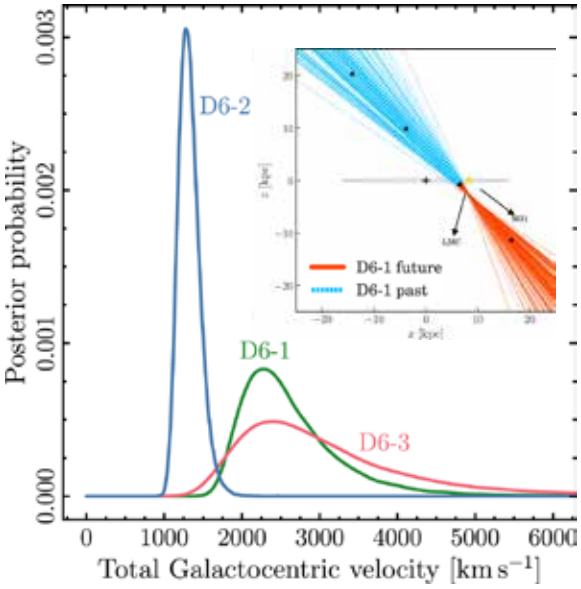
THE CONNECTION BETWEEN HYPERVELOCITY WHITE DWARFS AND TYPE IA SUPERNOVAE

Type Ia supernovae (SN Ia) are exploding white dwarf stars in binary systems. Because of their nearly uniform intrinsic luminosity, SN Ia play an important role as cosmological 'standard candles', allowing us to measure precise extragalactic distances and to explore the accelerating expansion of the Universe. Nevertheless, a complete physical understanding of SN Ia still eludes us: what are their progenitor systems, and how do they explode?

Ken Shen and a team of 25 researchers have used SALT in conjunction with data from ESA's Gaia mission to study this question. They concentrated on one of the models for SN Ia dubbed the dynamically driven double-degenerate double-detonation (D6) scenario, where the binary companion 'donor' star to the exploding white dwarf is another white dwarf that survives the explosion. After the supernova, the surviving companion star would be flung away at speeds between 1000 – 2500 km/s and be among the fastest-moving stars in the Galaxy. Shen and his collaborators searched for such 'hypervelocity' survivors in Gaia's second data release (April 2018) and discovered seven likely candidates. These stars were followed up with ground-based telescopes including SALT (via a Director's Discretionary Time programme led by Saurabh Jha from Rutgers University). The spectra of three of the stars were found to possess many of the predicted features for survivors of D6 SNe Ia. The combination of Gaia, which precisely measured the high speed motion of these hypervelocity stars in the plane of the sky, and ground-based spectroscopic observations, which provided a measurement of the radial component of the stars' motion, has shown that these are likely the first discoveries of surviving companions to SNe Ia.



Follow-up ground-based spectroscopy; the SALT data of star D6–1 shows it to be zooming away from us at 1200 km/s.



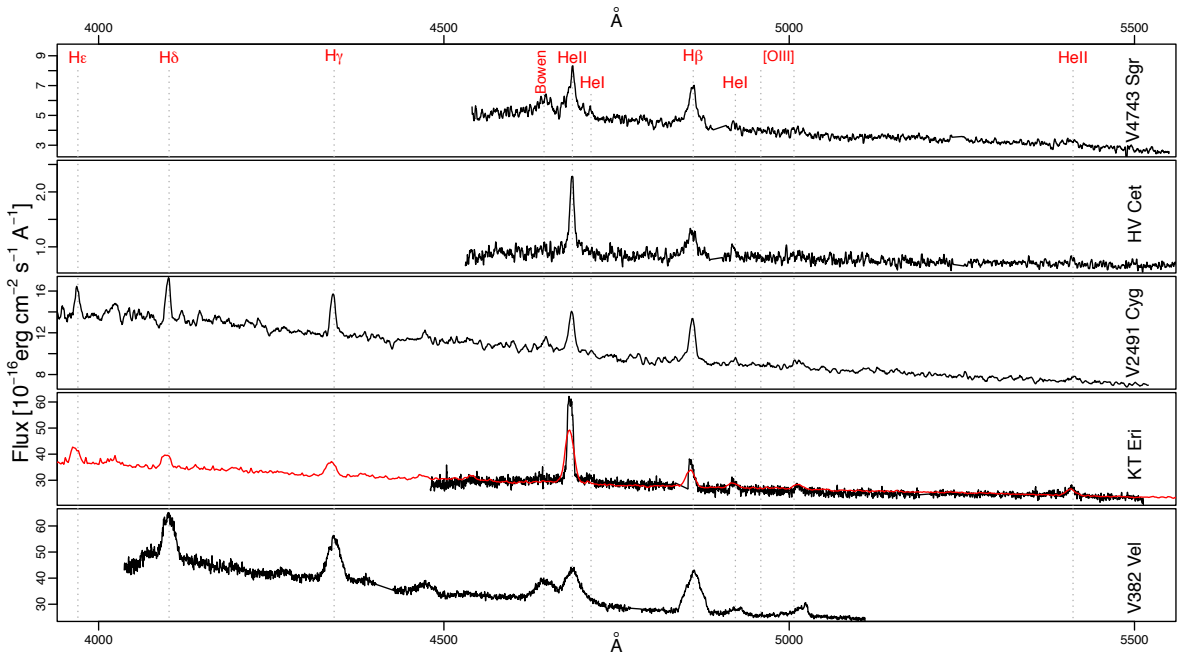
Estimates for the total Galactic speed of the stars, with the past and future trajectory for D6–1 shown in the inset.

Shen, K.J., et al., 2018/09, ApJ 865, 15: Three Hypervelocity White Dwarfs in Gaia DR2: Evidence for Dynamically Driven Double-degenerate Double-detonation Type Ia Supernovae

SALT STUDIES 'HOT' NOVAE RETURNING TO QUIESCENCE

Only few classical and recurrent novae have been identified or followed in their quiescent phase, yet the parameters of a binary system during 'quiet' accretion onto the white dwarf are fundamental to explain the outburst and to build self-consistent models. Ph.D. student Polina Zemko, together with her collaborators, decided to monitor the return to quiescence of nine classical novae that were extensively observed in a recent outburst and became known as luminous supersoft X-ray sources shortly after the eruption. The team observed five out of the nine post-outburst novae spectroscopically with SALT: all with the RSS, and in one case the observations were repeated with the HRS. Having obtained these good-quality SALT spectra, the team joined forces with the 1.9-m telescope of SAAO, with telescopes in the Northern hemisphere and, in one case, even with the Kepler satellite, to observe the others, including one that was already observed with SALT.

The authors found evidence that two of the novae, V4743 Sgr and V2491 Cyg, host highly magnetised white dwarfs and are 'intermediate polars'. They plan to continue this study investigating how the magnetic field shapes the outburst and evolution of novae. Notwithstanding initial results of previous research, the authors did not witness a significant influence of irradiation of the secondary by the hot supersoft source white dwarf causing high mass transfer for a prolonged period. Neither did they find the signature of nuclear burning in the inter-outburst phase of the recurrent novae, possibly implying intermittent mass accretion. Finally, the team studied the fragmentation of the nebular shell of the recurrent nova T Pyx, finding evidence of clumpiness already 3 years after the outburst.



Spectra of V4743 Sgr, HV Cet, V2491 Cyg, KT Eri and V382 Vel. Black: spectra obtained with SALT/RSS; Red: spectra obtained with the 6-m Big Azimuthal Telescope (BTA) of the Special Astronomical Observatory of the Russian Academy of Sciences.

Zemko, P., et al., 2018/11, MNRAS 480, 4489: Optical observations of 'hot' novae returning to quiescence

DISCOVERY OF AN UNUSUAL SUPERSOFT X-RAY SOURCE IN THE SMALL MAGELLANIC CLOUD

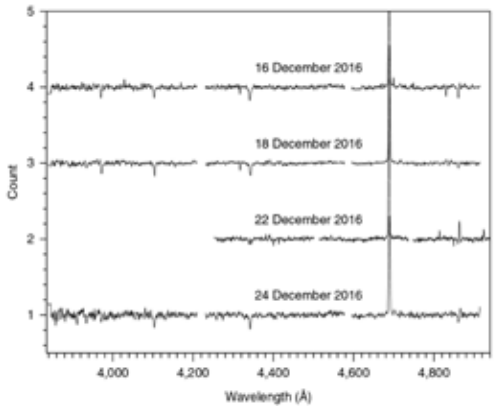
Supersoft X-ray sources (SSSs), first discovered in the 1990s by the ROSAT X-ray satellite, are white dwarfs that emit in X-rays and the extreme UV, typically characterised as thermal black-body emitters with temperatures up to about 1 million degrees. Such objects are assumed to be binary star systems in which high mass transfer leads to steady nuclear fusion on the white dwarf's surface. In eruptive classical novae, a runaway fusion event on a white dwarf is triggered once sufficient mass is accumulated, with the right temperature and density conditions. As novae decline in luminosity after the eruption, they usually emerge as SSSs at some point before cooling and dimming.

On 2 December 2016, a new transient object was discovered in the Small Magellanic Cloud, ASASSN-16oh, which was subsequently identified as a new SSS. The discovery was made by the All-Sky Automated Survey for Supernovae (ASASSN), a network of about 20 optical cameras distributed around the globe, which automatically surveys the entire sky every night in search of transient events. Optical follow-up observations were then conducted with SALT, initially under Saurabh Jha's (Rutgers University) supernova follow-up programme and then as part of the X-ray transient follow-up programme, led by David Buckley (SAAO), Phil Charles (University of Southampton) and Andry Rajoelimanana (UFS). Photometry was undertaken with the Polish OGLE telescope in Chile and with the Las Cumbres Observatory (LCO) telescope network, the latter as a DDT programme to look for short-term (~hours) variability, submitted by the South African group and conducted over a 34-hour period starting on the night of Christmas. Thomas Maccarone (Texas Tech University) and his collaborators also obtained contemporaneous X-ray and UV observations of ASASSN-16oh, with both the Neil Gehrels Swift satellite and the Chandra X-ray Observatory.

The data reveal that the optical light did not increase quickly enough to be caused by a normal nova explosion, while the Chandra observations show that the emission is coming from a region smaller than the surface area of the white dwarf. The source is also a hundred times fainter in optical light than white dwarfs known to be undergoing fusion on their surface. These observations, plus the lack of evidence for gas expelled away from the white dwarf, provide strong arguments against fusion having taken place on this white dwarf.

The researchers propose instead an alternative scenario: the X-ray emission probably comes from a 'spreading layer', that is, a belt on the surface of the white dwarf near the inner edge of the accretion disc in which a large fraction of the total accretion energy is emitted. The rate of inflow of matter through the disc often varies by a large amount and thus the X-ray and optical brightness of a system will vary. The transfer of mass in this case, however, is happening at a much higher rate than in any system known so far. All the SALT spectra show an intensely strong emission line from ionised helium, changing in velocity from night to night.

The fact that the transient SSS ASASSN-16oh is clearly not a classical nova, due to its lack of broad optical emission lines and different light curve morphology, shows that there exists an important alternative mechanism for producing supersoft X-ray emission. The team's conclusion is that the presence of an SSS cannot always be used as a tracer of nuclear fusion, in contradiction with the decades-old consensus about the nature of supersoft emission. The results may help explain the previously mysterious sub-luminous SSSs seen in nearby galaxies.



SALT optical spectra taken shortly after the optical peak brightness on 14 December.

Maccarone, T.J., et al., 2019/02, NatAs 3, 173: Unconventional origin of supersoft X-ray emission from a white dwarf binary

Ongoing research

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

The first and currently only **Large Science Proposal** on SALT is dedicated to "Observing the Transient Universe" and is led by David Buckley at SAAO. SALT is the ideal telescope for such a transient follow-up project: its queue scheduling provides the rapid response required (within days, or even hours) and having the full suite of instruments available at all times allows the observer to quickly switch between them, depending on the science requirements. The programme, which started in the second semester of 2016, was renewed from the second semester of 2018 through to the first semester of 2021. The international team now comprises more than 50 Co–Is, and telescope time is being charged to five different partners (RSA, UKSC, Poland, IUCAA and UW). Thirteen South African graduate students have been associated with this programme to date, with four completed and six current Ph.D. projects, as well as one completed and two current MSc projects. Seven overseas-based graduate students have also benefited from the programme. Typical object classes include X-ray/gamma-ray transients (including low and high mass X-ray binaries as well as gamma-ray bursts), cataclysmic variables and supersoft X-ray sources, optical counterparts to nuclear transients discovered from the Gaia and OGLE surveys, super-luminous supernovae and tidal disruption events, blazars and AGNs, and novae. By the end of 2018, 1073 kiloseconds of observing time have been charged to the participating SALT partners, half of which was spent in the 2018 calendar year with 253 blocks observed. The result in scientific progress is impressive: in 2018, six refereed papers were published (bringing the total count up to ten) with two more in press for early 2019; at least a further fifteen publications are in preparation. Data from the project are regularly presented at conferences and in Astronomer Telegrams.

In the two 2018 semesters, a total of 30 **Multi-Semester proposals** have been approved by the partner TACs, which is about twice as many as in 2017. Nine of these proposals were carried over from 2017, and one from 2015 ("The SALT gravitational lensing legacy survey" led by Stephen Serjeant of the Open University). There is an approximately even split between extragalactic and Galactic astronomy topics, plus two projects on exoplanets and their hosts, and one project on probing Dark Energy.

A number of individual projects have resulted in conference presentations or show important interim progress, of which we present a selection below.

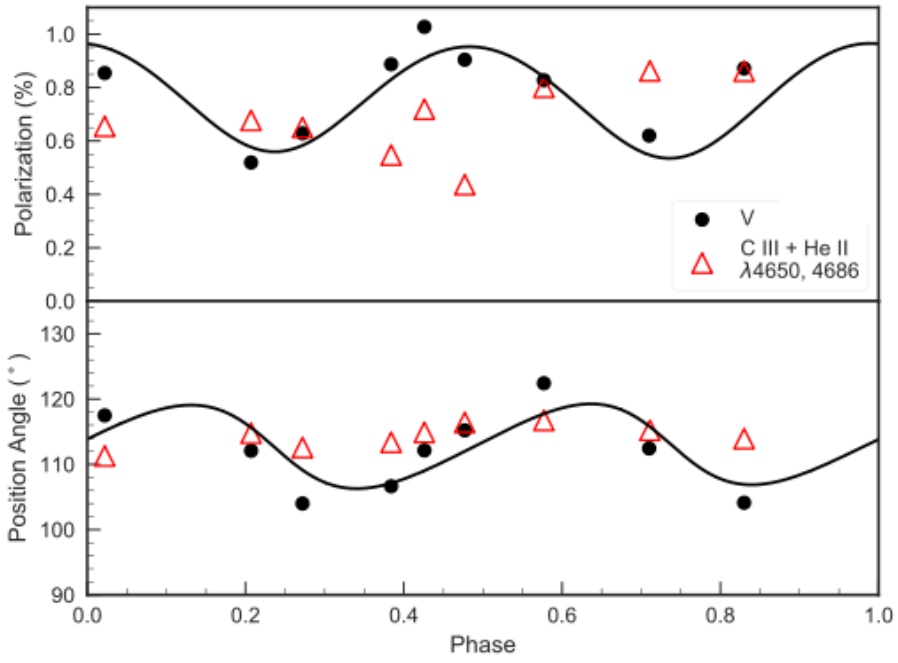
The team around **Valentina Cracco** continues their project on studying luminous supersoft X-ray sources associated with massive stars to search for white dwarf (WD) companions. High mass X-ray binaries, like the four examples the group has published on in 2018, must contain massive WDs and, if they do not lose mass in nova outbursts, they may be significant as progenitors of type Ia supernovae (possibly constituting the star formation-dependent component in the rate of these supernovae). A way to detect the presence of a WD companion to a Be star without a known orbital companion may be through a cyclic variability of the ratio of the *V*– to *R*–band peak intensity (due to the orbital period of the otherwise undetectable WD). This would be a more promising way of discovering Be + WD systems than 'waiting' for a supersoft X-ray flare. Considering the statistics of Be + WD binaries, the X-ray detections are probably only the tip of the iceberg, while optical studies are a more feasible avenue to increase the number of known systems. The research team plans to map two of their four detected binaries with their excretion discs to discover whether they host WDs or black holes, and, in case of WDs, whether they were viable supernovae Ia progenitors.

Carole Haswell's SALT/RSS spectroscopy of close-in planet hosts forms the basis of the Open University Ph.D. thesis of James Doherty. They have compiled a uniform database of over a hundred $\log(R'_{HK})$ measurements — an indicator for the Ca II activity and the most commonly used metric for comparing the chromospheric activity of F, G and K stars. Over 40% of the sample has anomalously low Ca II H&K line core emission, indicative of absorption in circumstellar gas ablated from their close-in planets. As part of their project, the team has established that WASP–43, a K-type star with a transiting planet, consistently exhibits anomalously high activity, suggestive of

magnetic star–planet interactions. A poster was presented at the "Cool Stars 20" conference at Boston, USA, and a comprehensive statistical analysis is underway.

On the synergy front, **Julie Davis** from the University of Wisconsin and her team have collected RSS longslit and MOS data over the last few observing semesters in support of the on-going COSMOS HI Large Extragalactic Survey (CHILES), conducted with the USA-based radio telescope Very Large Array. The goal of CHILES is to observe neutral hydrogen in emission over a continuous redshift range of $0 < z < 0.45$ using a thousand-hour integration of a single 30-arcminute pointing in the COSMOS field. The SALT longslit data are used in complement to the radio data to investigate neutral and ionised gas kinematics for a dozen galaxies which were selected from the nearest ($z < 0.1$) galaxies in the CHILES sample. The team studies interesting properties such as asymmetries, peculiar kinematics in galactic central regions, and misalignment of the optical and HI axes. The MOS spectra have been collected to obtain spectroscopic redshifts for use in radio spectral stacking experiments and in studies of galaxy groups in overdense regions in the CHILES volume.

Andrew Fullard reported at the AAS meeting on progress of his project on spectropolarimetry of the WR+O binary WR 42. Wolf–Rayet (WR) stars are evolved massive stars that produce strong emission lines and optically thick winds; in a binary with an O-type star (another massive star) this can result in wind–wind interaction and mass transfer. Spectropolarimetry is well-suited to analyse the geometry of the wind material, giving clues about the mass transfer rates and potentially inferring the rotation speed of the O star. A rapid rotation is required to fulfill one of the criteria for long-duration gamma-ray bursts, and rapidly rotating O stars are considered to be good candidates for such events. Andrew Fullard and his colleagues investigated the WR+O binary system WR 42 using SALT/RSS spectropolarimetry. They discovered that the C III + He II and C III/C IV lines show complex phase-dependent and velocity-dependent polarisation and position angle behavior, particularly across the atmospheric eclipse at phase 0.5 (see figure below). The *V*–band (continuum) polarimetry displays sinusoidal behaviour which is likely caused by the aspherical WR wind occulting the O star. The line polarization does not follow the sinusoidal phase behaviour, showing that the line forms and scatters differently than the continuum.



Polarization and position angle vs. phase, respectively, of the SALT/RSS data of WR 42 compared with the broadband Fourier fit of published data (solid line). Error bars are smaller than the symbols.

Student projects

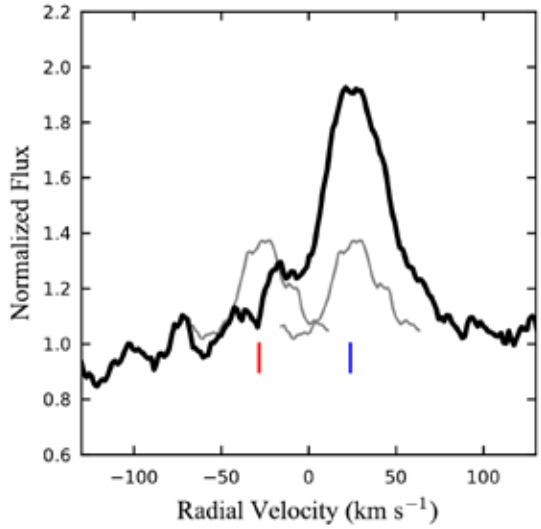
In compliance with SALT's strategic objective of Human Capital Development, a large number of projects involve students or are initiated by students. Some examples of ongoing student projects are presented here. Projects with publications in 2018 can be found in the research section.

Prasiddha Arunachalam is a fourth year Ph.D. student at Rutgers University working with Jack Hughes on the remnants of type Ia supernovae. Her focus is on determining the explosion energy and total iron ejecta mass of SN Ia remnants in the Large Magellanic Cloud. She is taking a multi-wavelength approach using both Chandra X-ray observations and SALT/RSS longslit spectroscopy.

Jack Hay is a fifth year Ph.D. student at Rutgers University working with Chuck Keeton to characterise the population of isolated compact objects (black holes and neutron stars) in the Milky Way using gravitational microlensing. He has begun a pilot study targeting events from OGLE with real-time SALT/RSS and HRS spectroscopy over multiple epochs to demonstrate the feasibility of characterising both lens and source spectra.

SALT DETECTS PULSED ACCRETION IN ECCENTRIC BINARIES

Ben Tofflemire from the University of Wisconsin–Madison (supervisor Bob Mathieu) obtained his Ph.D. in 2018 with his thesis on "Pulsed Accretion in Eccentric Binaries: An Observational Study of the Photometric and Kinematic Variability of Accretion in Short-Period, Pre-Main Sequence Binary Stars". While the interaction between a pre-main sequence star and its protoplanetary disk is fairly well understood, the star-disk interaction of binaries is much more complex, and in particular for short-period binaries where orbital resonances are capable of clearing out disk material on size scales of the binary separation. Ben observed the two eccentric systems DQ Tau and TWA 3A (the latter with SALT/HRS) and found a link between stellar accretion and the binary orbit. Both systems exhibit consistent bursts of accretion near their periastron passages, in agreement with predictions, but the newly discovered circumbinary accretion flows feeding preferentially the TWA 3A primary are unexpected.



Comparison of the He I λ5876 line at the high-accretion, periastron epoch (black) with a low-accretion, apastron epoch in (gray). Blue and red dashes mark the radial velocities of the primary and secondary, respectively, at periastron. The large increase in emission strength that is centered on the primary's velocity (blue) is compelling evidence for a burst of accretion that preferentially feeds the primary star.

Benjamin M. Tofflemire, University of Wisconsin–Madison, Ph.D., 2018

THE IMPACT OF IONISED OUTFLOWS ON THE SURROUNDING INTERSTELLAR MEDIUM IN DISC GALAXIES

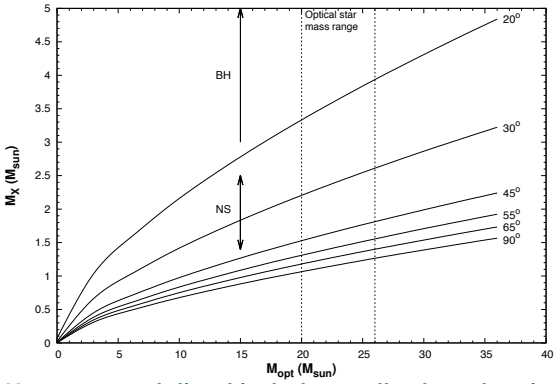
Keele University student Ameerah Al-Sadooni (supervisor Jacco van Loon) was awarded her Ph.D. in October 2018. Her thesis was solely based on observations Keele University obtained with SALT, a combination of Fabry–Pérot and long-slit spectroscopy. Ameerah studied two nearby spiral galaxies, the nearly edge-on NGC 4945 and the more face-on NGC 300, in detail. The former has an active but hidden nucleus with a nuclear outflow that was exquisitely well traced with the Fabry–Pérot spectral imaging. NGC 300 has an actively star-forming disc in which H II regions were found to impact upon the surrounding interstellar medium. Ameerah continues to conduct a large priority-4 programme with SALT to image edge-on galaxies to search for extra-planar gas and dust through low-resolution Fabry–Pérot imaging. In the meantime, she has returned to Iraq and to her faculty position in the Physics department of Babylon University.

Ameerah Al-Sadooni, Keele University, Ph.D., 2018

OPTICAL AND GAMMA-RAY STUDY OF GAMMA-RAY BINARIES

Itumeleng Monageng from the University of Cape Town (supervisors Vanessa McBride, Markus Böttcher and Shazrene Mohamed) was awarded his Ph.D. in December 2018 on multi-wavelength studies of gamma-ray binary stars. Such binaries are a small subclass of X-ray binaries with only seven confirmed systems known so far. Gamma-ray binaries comprise a compact object (neutron star or black hole) in an eccentric orbit around an early-type O or Be star. These fascinating objects display emission across the whole electromagnetic spectrum and are often defined by the feature of a peak above 1 MeV in their spectral energy distribution plot. Except for two cases, the nature of the compact object in gamma-ray binaries is unknown, leading to uncertainties about the origin of the observed multi-wavelength emission. As a result two competing models have been put forward to describe the origin of the emission, one invoking accretion of matter from the massive companion onto the compact object (the microquasar model) and another which involves colliding winds from the two components of the binary.

One goal of Monageng's thesis project was to use radial velocity measurements to obtain orbital parameters and to constrain the nature of the compact object of one of the known systems, 1FGL J1018.6–5856. Previous attempts have been hindered by poor-quality data as well as sparse orbital phase coverage. Itumeleng used SALT/HRS spectra to measure the radial velocities from cross-correlation techniques, where a Keplerian fit provided, for the first time, an orbital eccentricity. This allowed him to derive the geometry of 1FGL J1018.6–5856, which is particularly important for modelling of the system in the high-energy regime. Using the derived orbital parameters, Monageng could then put a constraint on the mass of the compact object, which he found to favour a neutron star.



Mass–mass relationship between the two stars in 1FGL J1018.6–5856 as a function of inclination angle which is obtained from the orbital parameters derived from the radial velocity fit. The x-axis of this plot is the mass of the early-type companion, the mass-range of which can be inferred from the spectral classification (20 – 26 Solar masses in this case). Based on the amplitudes of the lightcurves from high-energy observations, one can then put a lower limit on the inclination angle, which for the case of 1FGL J1018.6–5856 favours a neutron star (a black hole would require lower inclination angles than is supported by the high-energy lightcurves).

Itumeleng Monageng, University of Cape Town, Ph.D., 2018

SALT conference

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SCIENCE HIGHLIGHTS

ADVANCES WITH SALT

13 – 16 November in Pretoria, South Africa

The third SALT Science conference, "Advances with SALT", followed in sequence that began with the 2015 "Science with SALT" conference in Stellenbosch, South Africa, and a smaller, more focused meeting in Poland in 2017. The conference was held directly after the SALT board meeting at the National Research Foundation (NRF) headquarters in Pretoria, in the Albert Luthuli Auditorium. The excellent facilities made for a very pleasant and productive environment, with talks and breakaway discussion sessions over the course of three days.

There were 80 participants, with more than a third coming from outside of South Africa. Locally, attendees from five South African universities, two national facilities, the NRF and the Department of Science and Technology (DST) participated, while almost all the SALT partner institutes and a number of other organisations in the USA, Australia and Europe were represented by the international visitors. The diverse group included many students and postdocs. We'd like to thank the NRF for their sponsorship of the meeting and providing travel support that enabled many of the young local and international researchers to come, contributing to a vibrant and dynamic atmosphere.

The presentations covered a multitude of astrophysical sources over a huge range of scales, with sessions on transients, binary stars, nearby and distant galaxies, AGN and quasars. There were talks on exciting, relatively new fields for SALT like asteroid trails and exoplanets, and a number of talks highlighted exciting future directions. Time for less formal workshop sessions on operations, software, data reduction and ideas for new instrumentation enabled useful discussions, problem-solving and brainstorming. Members of the SALT technical and astronomy operations team provided valuable input on engineering and operational aspects, and it was great for the service observers in Sutherland to connect with SALT investigators from all over the world who use the data they have taken. On the technical side, we heard updates on the near infrared spectrograph, due to be installed on SALT in 2020, and plans for the next generation of instrumentation. The director of SAAO, Petri Väisänen, presented the 'intelligent observatory' concept for the Sutherland plateau, with planning underway for fast, automated multi-telescope response to transient detections. The meeting highlighted SALT's ability to rapidly react to targets of opportunity, with queue-mode observing and immediate access to a range of instruments with interesting and unusual modes. These already enable SALT to play an important role in multi-wavelength, multi-messenger campaigns, fulfilling a niche amongst large telescopes. In combination with new facilities in South Africa like the MeerKAT radio array and its `optical twin' MeerLICHT (they will both observe the same spot in the sky simultaneously), and with upgrades to existing telescopes and instruments, there is enormous promise for exciting new science to come. Thank you to everyone who participated in the conference. We look forward to celebrating further advances at future SALT science gatherings!

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OPERATIONS

Astronomy operations

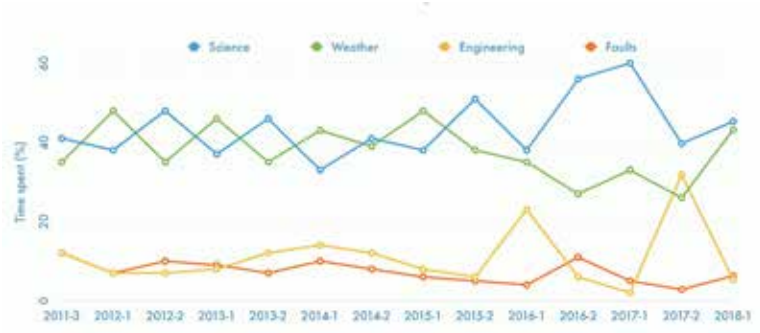
The year started with some excellent news: SAAO and SARAO forged an agreement to jointly fund the **SALT Generation 1.5 instrumentation** package as outlined in the SALT Strategic Plan, which was approved by the SALT Board in November 2017 and ratified in 2018. This initiative includes, among other things, a new maximum-efficiency spectrograph for transient science (MaxE) and an in-depth investigation into the instrument capabilities of the HRS High-Stability (HS) mode for exoplanet science. Preliminary results obtained in June using a new iodine cell on extremely bright stable stars indicate that the HS mode is capable of radial velocity precision down to ~5 m/s. Further efforts to refine this are being led by our new SALT Observatory Scientist, Lisa Crause.

During June, a number of SALT/SAAO employees and researchers associated with SALT partners attended the **SPIE conference** on "Astronomical Telescopes and Instrumentation" in Austin, Texas (USA), presenting a total of 19 papers in six of the conference's sub-categories. SALT also had a display booth at the conference, which was visited by a large number of people through the course of the exhibition.

From 13 – 16 November 2018, immediately following the November SALT Board Meeting, a 3-day **SALT conference** entitled "Advances with SALT" was held at the NRF headquarters in Pretoria, South Africa. The conference was well attended by over 80 participants and was a successful mixture of standard presentations and 'un-conference' sessions (that is, informal group chats) about various topics of interest, ranging from the current design for MaxE through further discussions on the SALT transient program to optimising SALT observations. In December, a SALT Operations survey questionnaire was sent out; it included feedback on the conference which was extremely positive, particularly on the 'un-conference' sessions. The results on the survey will be analysed in detail and published in early 2019.

Semester statistics

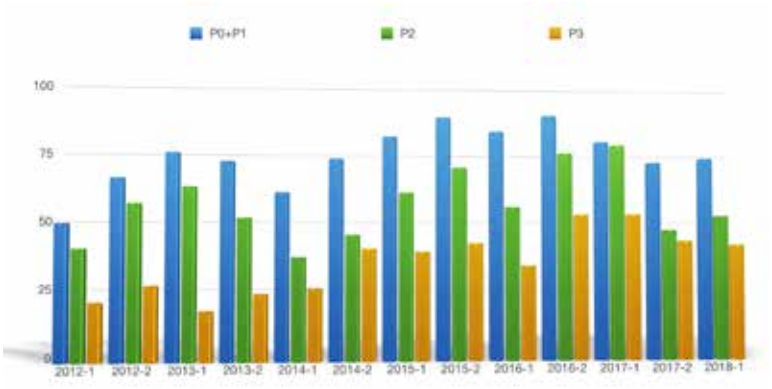
The 2018 South African winter saw the return of the standard weather statistics to the Northern Cape and to Sutherland, ending the astronomically-awesome weather of the last couple of years. The amount of time available for science, after the record breaking year 2017, was back to being comparable to the long-term average of 44%, with 40% for the semester 2017-2 and 45% for 2018-1. While the weather was still good in the 2017-2 semester with an absolute record low of 27% time lost, the total of seven weeks of planned engineering shutdown (to mainly work on the guider, tracker, optics, and cabling) had a severe impact on the science time of that semester, with an unprecedented 32% engineering time. The science time was further affected by several technical problems arising unexpectedly from the new RSS guider, which was installed during the March/April shutdown, also impacting the science productivity of semester 2018-1.



SALT time usage per semester

Despite these problems, however, the new RSS guider proves to be a significant improvement over the old. It is able to correct for rotational drift, thus making MOS acquisition much easier, and acquisition times for MOS, and possibly longslit RSS, are due to be significantly reduced in the future.

The reduced science time, compared to previous semesters, as well as the increase in engineering time were the main reasons for the slightly lower priority completion rates, especially among the high priority bands, which are generally the most demanding in terms of sky conditions. The P0+P1 completion, though lower than last year (73% vs. 83%), is, however, comparable to the long-term average of 73%, and while the P2 completeness at 50% is considerably lower than the average of 56%, the P3 completion (with the least demanding sky conditions) at 43% is accordingly higher than the average of 36%.

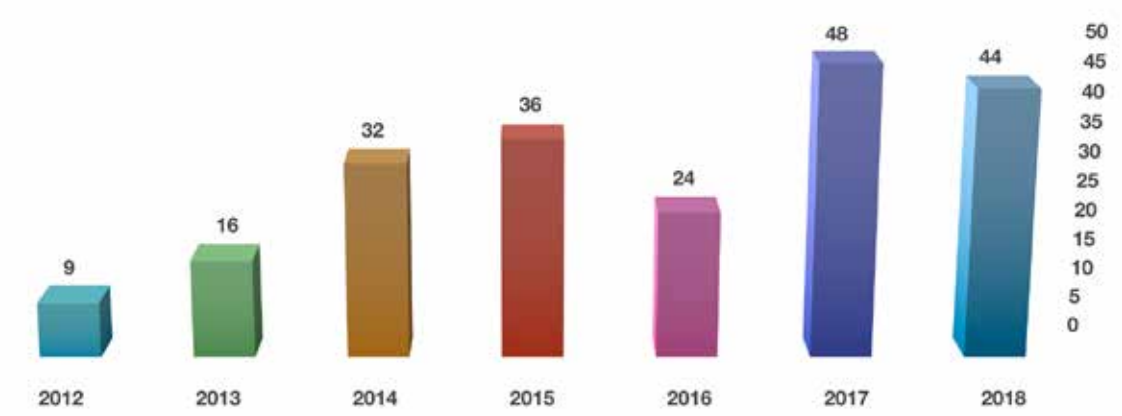


Completeness per priority in percent

Publication statistics

A total of 45 refereed papers were published during the year 2018, close to the record of 49 papers from 2017 and keeping SALT along the same publishing trends as other international facilities. One out of the 45 SALT publications was instrument-related (as was the case in 2017); the majority of the 44 science publications this year came from the stellar community (24, or 53%), while 15 (33%) are extragalactic; three papers are related to supernovae, and the remaining two refer to the interstellar medium on the one hand and to the gravitational wave event GrW170817 on the other. An additional 19 SPIE technical conference proceedings papers were published, which is four more than at the previous SPIE conference in 2016.

The science publications are still based mainly on RSS data (63%), with most of these being longslit observations. HRS publications, though, are ramping up, doubling last year's seven publications to 15 this year. This is likely influenced by the release of the HRS pipeline and also due to its increased usage at the telescope: over the last three semesters, HRS and RSS have shared the sky nearly equally, with RSS taking the better sky conditions while HRS is able to make better use of the previously less sought-after bright-Moon and bad-seeing conditions. The year also saw the second publication using the Fabry–Pérot capability of the RSS instrument.



Refereed papers based on SALT science data (i.e., excluding instrument-related publications), from 2012 onwards.

User support

Several key software issues were identified this year and received attention from the team, such as the need for a fully searchable data archive, a more automated data quality control system and an upgrade and simpler installation of the SALT data reduction pipeline, probably via Docker. All of these projects are expected to be completed during 2019.

The PyHRS pipeline for the HRS instrument is no longer supported due to the departure of the SALT Data Manager at the beginning of the year, but the MIDAS-based pipeline for the HRS LR, MR and HR modes is still available and fully supported and documented.

Gravitational wave event proposals

A new policy for proposals covering gravitational wave (GW) events aims at providing a simple framework (available at the SALT Astronomer's webpages) to ensure openness and fairness across the SALT community. Given its geographical location and its large aperture, SALT has a key role to play in world-wide GW event follow-up campaigns. To the benefit of the entire community and to maximise SALT's scientific output, such follow-up SALT observations should be coordinated. To that end, a new proposal category (GWP) was created which allows a single (consolidated) proposal per GW event. Time will be taken from the DDT time allocation. Notifications will be sent to all users who have signed up to a dedicated mailing list. Users can subscribe to, unsubscribe from and send messages to this list using the SALT Web Manager. Data obtained for GW event proposals is non-proprietary.

Personnel

Petri Väisänen took up his position as the new SAAO Director in January 2018, with Encarni Romero Colmenero taking over from him as Head of SALT Astronomy Operations at the same time.

Steven Crawford resigned from his position as SALT Data Manager at the end of January 2018. The position was fully SAAO funded and, as such, this role was re-assessed and re-structured in the context of a single SALT & SAAO observatory, and a new SALT Astronomer (SA) position with a pipeline focus was approved by the SALT Board and advertised at the end of 2018.

SALT vacancies were temporarily filled by two Ph.D. students awaiting their official Ph.D. award confirmation, Itumeleng Monageng and Rajin Ramphul. Later in the year, two new SAs joined the team in September and October, respectively: Moses Mogotsi, who is actively involved in the RSS-NIR instrument, and Danièl Groenewald, with a focus on spectropolarimetry support.

Sifiso Myeza joined the SALT Astronomy Operations team in 2018 with a one-year contract as a junior software developer. He has made several significant contributions, such as designing, developing and implementing the new SALT statistics webpage for the Time Allocation Committees, several Web Manager upgrades, as well as key contributions to the Astro-software team. After a competitive application process at the end of the year, Sifiso was selected to return to the team in 2019 as a fully qualified software developer.

Technical operations

A six-week **SALT shutdown** was conducted during March and April. On the agenda were: the installation of the new RSS guider; the replacement of the telescope's Rho cable wrap (the original wrap was overpopulated and difficult to work with, so a new and more suitable double wrap was introduced while the telescope was offline); the inspection of the RSS optics; debugging of the polarising waveplate mechanism; the replacement of the optical fibre cable between the SALT and SAAO server rooms and the improvement of the cooling system for the SALTICAM CCD controller.

The installation of the **new guider** for the RSS was a major achievement for the year. This system introduces new features that were not available with the original guider. The main aims were to significantly improve the optical throughput (to enable guiding on V = 18 mag stars using 15-second integrations), to add rotational guidance functionality (using two guide stars) and to introduce active telescope–focus control. These are long-outstanding science requirements that were not met during the telescope project phase. The development had been completed in time for the March/April shutdown. The commissioning of the guider, however, was a challenge and proved more difficult than anticipated due to the system having to interact with a number of the telescope's key sub-systems. The new guider is now working reliably and to specification, with acceptance testing scheduled to take place in early 2019.

With the **RSS** on the ground, the various collimator optics could be inspected and cleaned. The Field Lens and Main Group optical assemblies, being relatively exposed and vulnerable to dust, were cleaned once they had been extracted from the instrument. Both were found to have developed minor leaks, with the index-matching coupling fluid escaping from the storage bladders located at the edges of the lens cells. The bladders and coupling fluid were replaced before all the optics were re-installed. The spectrograph's problematic waveplate mechanism (that can only be reached for maintenance once the RSS is removed from the telescope) also received attention: a loose encoder scale on the half waveplate was repaired and tested, along with some software modifications to ensure reliable and efficient operation of the polarimetric modes. The RSS, with its new guider onboard, was re-installed on the 10th of April.

The **HRS** required attention several times during the year: the first phase of commissioning the HRS High-Stability mode in May included working closely with Paul Butler to test one of his custom-built iodine gas absorption cells. Modifications are necessary to incorporate the new iodine cell as a permanent fixture of the HRS. Later in the year both the Red and Blue cryostats showed signs of degraded vacuum integrity that the standard pump-and-bake procedures could not rectify. These systems were initially expected to need annual routine maintenance, but it is now clear that the relevant timescale is closer to four years. The process was successfully completed by members of the Cape Town Instrumentation team and SALT Operations staff. In late October, the instrument's mode selector failed and was fixed early in November, which required the HRS vacuum tank to be opened for the first time in four years of operation.

While the RSS and HRS were offline for several weeks in total, **SALTICAM** and **BVIT** remained in routine operation throughout the year, although the SALTICAM shutter needed maintenance in May. The **RSS detector** failed intermittently during June, due to overheating of its controller electronics. The instrument remained in use during this period as the repairs were done during the daytime. The **telescope dome and shutter sealing** proved to be very successful, no significant water ingress occurred during severe rain and hail storms occurring less than a week apart during January.

It is noteworthy that the faults and technical downtime reached a record low of 2.8% at the end of the 2017-2 semester, just prior to the March shutdown. Unfortunately, during the 2018-1 semester (May to the end of October) this metric was affected by the problems with the RSS guider and had regressed to 6.2% by the end of the semester.

An important **asset renewal project**, to replace the primary mirror segment positioning system (SPS) electronics, has started and the units will be received in September 2019. The current system is more that 12 years old and its spare parts are no longer available. Various other asset renewal projects, such as replacing the general and instrument air compressors are also underway.

SPIE conference and McDonald Observatory visit

A strong contingent of thirteen SALT Operations staff attended and made oral and poster presentations at the prestigious SPIE Conference on "Astronomical Telescopes and Instrumentation", from 10 – 15 June in Austin, Texas (USA). Four of those were first-time authors and speakers. Directly after the SPIE conference, a party of ten Observatory staff visited McDonald Observatory and the HET from 17 – 20 June, where they met with their northern hemisphere counterparts, exchanging knowledge and experience spanning an array of topics. Two members of the group were from our SALT Collateral Benefits Program (SCBP), with particular interest in McDonald Observatory's impressive tourism and outreach operations.

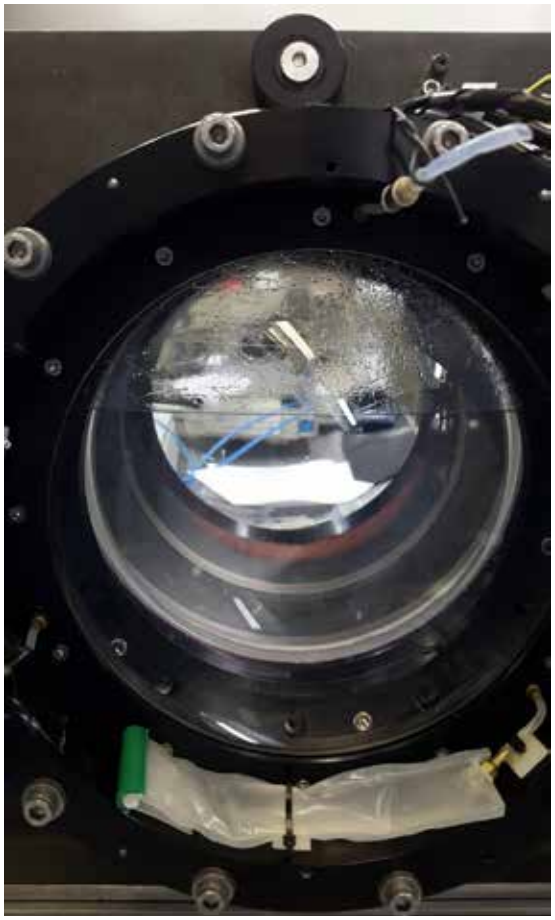
Personnel

The SALT Board approved four new positions for the Technical Operations team in April 2017. One position in Cape Town was filled quite quickly, while the three positions in Sutherland were only filled in May to July of 2018 by transformation candidates. This long recruitment process delayed some of the development and asset renewal projects. Two of the most senior SALT Technical Operations personnel are being seconded to SAAO to work on new instrumentation projects funded by the South African Radio Astronomy Observatory (SARAO). SARAO will second three persons to take over some of their tasks for the next two to three years.

Health and safety

Four safety incidents occurred during this period, two work-related and two rather serious, but not work-related incidents. During one of the work-related incidents the tracker drawbridge suffered superficial damage; no one was injured during either of these incidents. In one of the non-work-related incidents, the SAAO ambulance was not serviceable and thus could not transport a patient to a hospital in Cape Town. The child of a staff member was injured during the other non-work-related incident.

Another fire drill, which included the Sutherland Site's small fire-fighting unit, was held. The equipment worked well but it was noted that it will be insufficient to contain and extinguish a significant fire in the SALT telescope chamber. A more capable permanent installation is being considered, including standard fire hydrants fed by booster pumps from the water reservoir and equipped with standard pipes long enough to reach any fire in the building and its service rooms.



Draining of the RSS coupling fluid. Below the lens one of the bladders is visible.

Instrument news

July saw the restart of the project to prepare the telescope and its sub-systems to receive the **new near-infrared (NIR) spectrograph** that is being built by the instrument team at the University of Wisconsin (UW) in Madison; these efforts had been put on hold to give the RSS guider team time to debug the guider after installation. The various sub-projects associated with SAAO's side of the work include replacing the telescope's atmospheric dispersion compensator, correcting the Rho drift of the telescope (a latent defect uncovered after the telescope project phase), modifying the fibre-instrument feed to accommodate the NIR fibre cable and developing the relevant instrument control and data reduction software. On the UW side, most of the collimator optics have now been manufactured and an 8-metre-long sample IFU cable has been built for testing purposes. In the near future, all of the available hardware will be transferred to the NIR thermal enclosure, where it will undergo testing at the instrument's operational temperature of –40°C. The NIR spectrograph is now expected to be delivered to SALT in 2020.

As part of the Generation 1.5 instrumentation package, a high-efficiency spectrograph is to be designed and built for SALT over the next two and a half years. The new **maximum-efficiency spectrograph (MaxE)** will support the SALT strategic plan by accommodating the expected increase in transient science (based on triggers coming from MeerKAT and LSST, among others). The MaxE project will kick off in early 2019 as part of the NRF/SALT Strategic Instrumentation Initiative, with a number of newly hired people, and some seconded from SARAO, joining the team. Both the optical design of the spectrograph and the detector package will be developed in-house to leverage SAAO's existing instrument building capacity and expertise. The project will also create additional capacity within the SAAO Instrumentation group to support the development of future instrumentation for SALT (Gen 2) as well as for other observatories. The next steps in the timeline are to finalise the project processes and the scientific requirements for the instrument while developing concept designs for review. These concepts include the possible use of a spherical grating spectrometer. The main characteristics of the instrument are a low-resolution (R ~ 1000) optical (~ 3800 Å – 7600 Å) spectrograph that will be fed by a short-fibre IFU at the SALT focal plane. The IFU is not intended to provide spatial sampling but rather to optimally collect the target flux while simultaneously sampling the background for accurate sky subtraction, resulting in overall maximum-efficiency single-object spectral typing and redshift determination using SALT.

THE HIGH-RESOLUTION SPECTROGRAPH (HRS)

The HRS commanded a fair amount of attention throughout the year.

The **development of exoplanet science capabilities** entered a new phase with the start of commissioning the HRS's High-Stability (HS) mode. A preliminary study, following the recommendations in the SALT strategic plan from 2017, showed that the existing commercial iodine cell contained too much iodine, saturating the absorption lines and therefore hampering wavelength accuracy. Consequently SALT purchased a new, custom-built iodine gas absorption cell from exoplanet specialist Paul Butler (a pioneer of this powerful technique for detecting planets) in January, and in May Paul spent two weeks in South Africa to adapt his intricate precision radial velocity data-reduction pipeline to accommodate the HRS spectra. During that time, we conducted an on-sky engineering campaign, observing a number of extremely bright stars with stable radial velocities through the new iodine cell. While not spectacular, those early results (RMS velocities of order 5 m/s) were certainly encouraging, and work is in progress to optimise this mode for active service. The new housing and temperature control system for the iodine cell will be completed early in 2019.

Additionally, simultaneous-Thorium–Argon (ThAr) specialist Arpita Roy from Caltech is working with SALT Observatory Scientist Lisa Crause

and SALT Astronomer Rudi Kuhn to evaluate the internal stability of the spectrograph using arc spectra. Those results will factor into the decision as to whether or not to pursue the HRS–HS mode's simultaneous-ThAr option, as well as the development of a laser frequency comb for the HRS.

The guiding principle for the HRS is to do as little as possible to the instrument. But during July **the two cryostats** began showing signs of needing maintenance (for the first time in almost four years) as both cameras struggled to hold vacuum and maintain their cryogenic operating temperatures. Downtime was scheduled for the next dark week, to limit the impact of taking the spectrograph offline. The Red and Blue cameras were then warmed up, detached from the instrument's huge stainless-steel vacuum tank and very carefully driven to the SAAO's detector lab in Cape Town. The plan was to extract the various charcoal getters from the two dewars in order to vacuum-bake them at high temperature to recharge them. We also decided to bake the ion pumps that help to maintain the vacuum integrity of the cryostats. After leak-testing the dewars with helium using a residual gas analyser, the ion pumps were disconnected and the cryostats opened to access the charcoal getters.

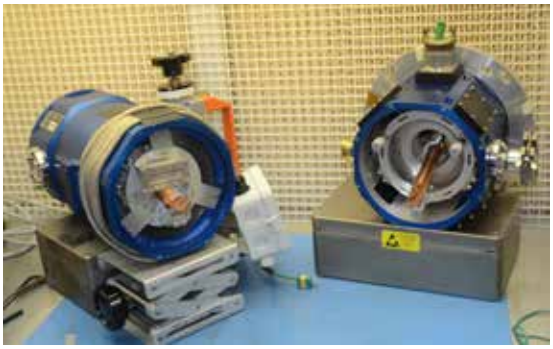
Totally unexpected was the discovery of vast amounts of metallic 'sand' inside each of the ion pumps. This was equally surprising to the ion pump manufacturers, yet their technical specialists confirmed that this is normal behavior for ion pumps running at the sorts of pressures our cryostats operate at. After painstakingly removing the offending particles from the cryostats, we proceeded to bake the charcoal and replace both ion pumps. The reassembled dewars were then vacuum-baked as well before being driven back to SALT and reinstalled on the tank.

The Blue camera (pictured) went back exactly as it should have, but the Red proved problematic. Design issues with the copper cold-finger assembly on the Red dewar make it vulnerable to misalignment of the detector. To our dismay, frames taken once the system was back at its operating temperature of –120°C revealed a tilted CCD. A portable clean-tent was set up in the spectrometer room beneath the telescope and used for the open-cryostat surgery required to re-align the chip. Our first attempt halved the problem and so a second iteration was needed. Fortunately, this final tweak could be done with the Red camera still connected to the tank, avoiding some of the risk associated with removing and re-attaching the camera. The impact on science operations was limited, as much of the work was done during dark time and, incidentally, while Sutherland experienced a fair amount of bad winter weather.

After a few months of stable operation following these violent interventions, **the mode selector** – one of just four moving parts inside the vacuum tank – seemed to be moving slower than it should. Various non-invasive tests confirmed that this mechanism (which drives a mask with a slot up and down to select the relevant pair of fibres for the required HRS mode) needed attention. This meant having to open the vacuum tank, which we try to avoid at all costs (it was last done back in 2014). That said, opening the tank does afford a great opportunity to train new staff, as well as to commune with the spectrograph's spectacularly beautiful optics!

The mode selector had to be removed from the tank for a proper inspection, which revealed that the vacuum grease on the bearing rails had become quite sticky. The old grease was cleaned off and a minute amount of fresh vacuum grease was applied. The mechanism was put through its paces to ensure that all was behaving as it should before it was re-installed.

The iodine cell work done on the High-Stability bench earlier in the year had slightly disrupted the incredibly sensitive alignment of the HS mode's **fibre double-scrambler**. Having the tank open to access the mode selector offered the ideal opportunity to re-align those optics as one can then inject light into the system from both ends and finesse the alignment.



RSS GUIDER UPGRADE

After more than a decade of service, the RSS guidance system was replaced by a new modular, removable system. The upgraded RSS Guider, also known as the Prime Focus Guidance System (PFGS), was installed onto the telescope during the shutdown in March/April. The replacement of the RSS Guider was necessary to enable instrument focus and rho-rotation feedback, to allow offsets of 0.05" precision, and to increase the number of usable guide stars. Spares were also no longer available for the previous guidance camera. With the replacement camera and direct imaging, we are now able to guide on stars two magnitudes fainter than was possible previously.

The guider module is mounted to the RSS just before its focal plane and allows selecting two guide stars within the telescope's 10-arcminute field of view. The optical design uses off-the-shelf optics to re-image a 24 x 24 arcsecond portion of the telescope focal plane onto a small, un-cooled, integrated detector. A moveable, custom, 14 mm square pyramid wavefront sensor at the intermediate pupil allows focus detection by splitting the beam – creating two images of the guide-star at the detector.

Each detector, along with accompanying optics, is mounted on two off-the-shelf precision linear stages from MISUMI Corporation and can be positioned to within 2.5 µm via small NEMA 11 stepper motors and linear grating encoders from MicroE Systems. Two of these probes were created for the guider, each of which patrols one half of the field. The PFGS is kinematically mounted and can be removed for maintenance.

A dedicated National Instruments CompactRIO running a real-time Linux operating system controls and manages all aspects of the guider's operation. Closed-loop motion control of the stepper motor stages allows accurate, reliable and safe operation. The system is integrated with the rest of the telescope control system via NATS middleware.

Commissioning results confirmed that the system meets specification with probes positioned to better than 10 µm (0.05 arcseconds on sky). Closed-loop guidance achieved stabilisation of the focal plane to within ± 0.13 arcseconds RMS in translation, ± 16 µm RMS in focus and ± 300 µrad RMS in rotation. This improvement in positioning accuracy, combined with focus feedback, allows better quality science to be gathered in less time. The PFGS also allows translation, rotation, and focus stabilisation of the RSS focal plane to be achieved.

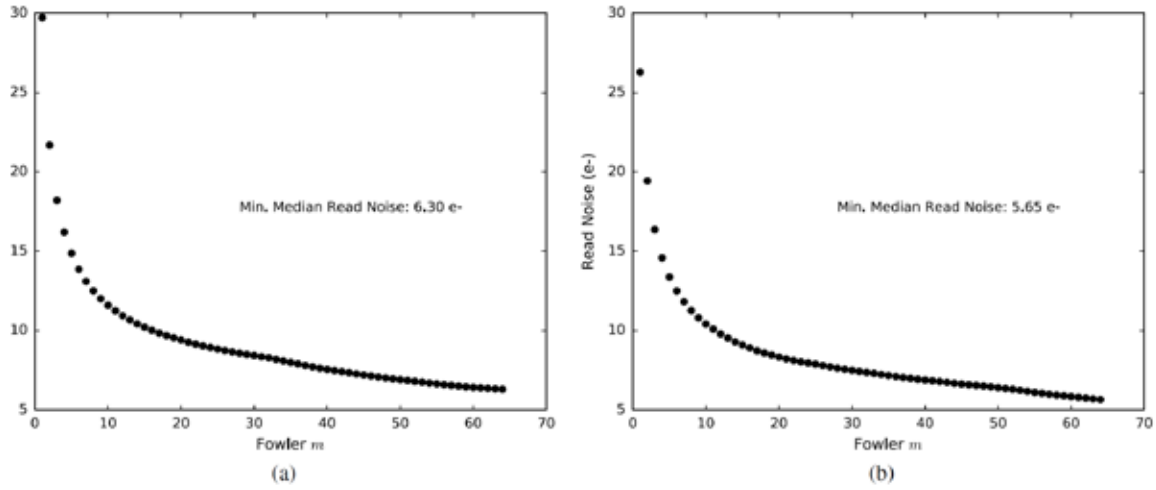
The RSS, with the new guider on-board, is being lifted to the tracker for re-installment.

OPTIMISATION AND PERFORMANCE OF THE NIR DETECTOR SYSTEM

The near-infrared (NIR) hosts a wealth of spectral features that can be used to study astrophysical processes in the universe. Observing these processes requires NIR spectrographs. At the University of Wisconsin–Madison, a team led by Marsha Wolf is building and testing SALT's upcoming NIR spectrograph. The original design had the instrument placed at prime focus, to work in tandem with SALT's workhorse instrument, the Robert Stobie Spectrograph (RSS). But the final design more sensibly places the NIR spectrograph in a thermal enclosure (cooled to –40°C) in the spectrometer room beneath the telescope. The instrument will be fed by a 40-metre long fibre cable carrying a total of 247 fibres, arranged in a hexagonal bundle at the IFU head and two small sky bundles, all fanning out into a pseudo-slit where they enter the spectrograph, which will operate over a wavelength range of 0.9 to 1.7 µm. This wavelength range offers different science capabilities, but also presents technological challenges compared to spectrographs operating in the visible, specifically regarding the detector systems: NIR detectors function differently to CCDs, having higher noise, being more sensitive to background and being plagued by persistence.

Greg Mosby and the NIR instrument team have now published the final design and the completed characterisation and optimisation of their chosen detector system, a HAWAII–2RG (H2RG) HgCdTe detector from Teledyne, controlled by the SIDECAR ASIC and an ISDEC card from India's SALT partner, IUCAA. The team has reduced the correlated double sample (CDS) read noise to ~20 e^- for 200 kHz operation by optimising the ASIC settings. The read noise can be further reduced by a factor of three (reaching ~7 e^-) using Fowler sampling techniques and by a factor of two (reaching ~11 e^-) using up-the-ramp group sampling techniques. The Fowler approach samples the initial pedestal and final voltage of a pixel multiple times to decrease read noise, while up-the-ramp group samples the voltage of a pixel as the signal is integrated to allow fitting a line to determine pixel flux.

A low thermal background of the detector system is critical to achieve sky-limited performance on the telescope. The team measured the performance of the cooled detector system inside a –40°C instrument enclosure together with an optional bandpass 1.55 µm cutoff filter (which will be offered to the observers). The background rate with the cutoff in place (based on 1800s exposures) was estimated to be 0.18 e^-/s, while the background measured at 0.88 e^-/s without the cutoff filter. Since the NIR sky is relatively bright compared to most faint astrophysical objects, Mosby and his team also present equations to quantify the conditions for sky-limited observations using the given sampling techniques.



Median read noise as a function of Fowler reads in (a) bright and (b) faint mode for the RSS–NIR detector. Using Fowler sampling, read noise can be reduced by a factor of 3 to 4 when using 64 reads.

Mosby, G., et al., 2018/01, JATIS, 4: Optimization and performance of the Robert Stobie Spectrograph Near-InfraRed detector system

THE NEW NEAR-INFRARED INTEGRAL FIELD SPECTROGRAPH (NIR)

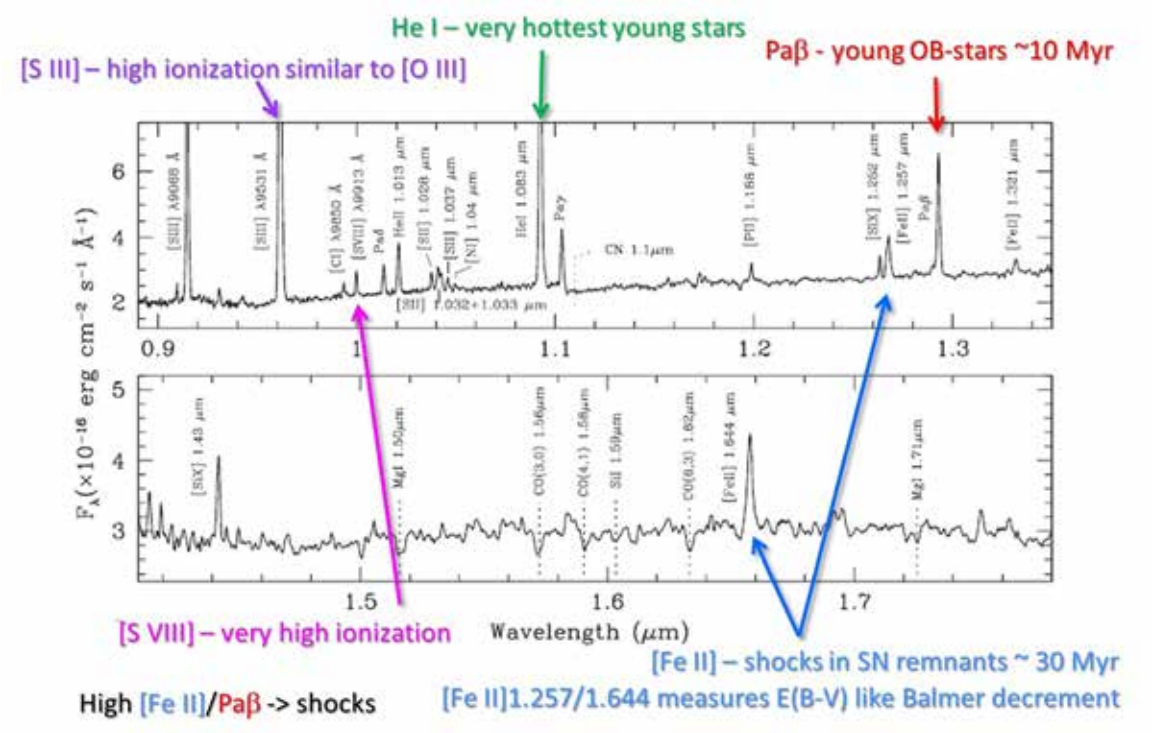
Recent and ongoing integral field spectroscopic (IFS) surveys are providing unprecedented views into galaxy evolution by examining the spatial properties of large numbers of individual galaxies. However, stellar population synthesis modeling to derive the star formation histories of galaxies from their optical spectra often runs into problems in distinguishing the youngest stellar populations (few Myr) in the galaxy due to a lack of sufficient young stellar spectra included in the models. Supplementing these studies with follow-up near-infrared (NIR) IFS data will provide important constraints on the most recent star formation in the galaxies since the NIR region contains additional information that is particularly powerful when combined with optical survey data on specific galaxies. Some of the NIR lines originate in physical processes with short timescales, so if detected, their presence can set limits on the star formation history of a galaxy. For example, H–Br line emission (1588, 1611, 1641 nm) that is formed by recombination in ionised gas will fade after ~8 Myr, while Fe II 1644 nm emission that is formed by shock-excited gas produced by supernova remains observable significantly longer for ~ 35 – 55 Myr. The combination of these lines can be used to constrain the timing and duration of very recent star formation.

The design of the SALT/NIR integral field unit (IFU) is optimised for sampling nearby galaxies with 217 fibres over a spatial extent of 21 x 33 arcseconds on the sky. Each fibre subtends 1.3 arcseconds. The table compares the SALT/NIR IFU instrument parameters to existing optical IFU instruments.

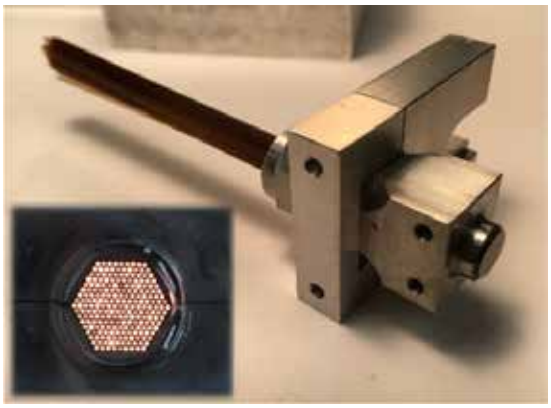
Survey/IFU	Fibre Size (arcsec)	Number of Fibres	IFU Size (arcsec)	Spectral Resolution (R)	Spectral Coverage (nm)
CALIFA[1]	2.7	331	74 x 64	850, 1650	370 – 700
SAMI[2]	1.6	61	15	1800, 4300	375 – 575, 630 – 740
MaNGA[3]	2	16, 37, 61, 91, 127	12 x 10, 17 x 15, 22 x 19, 27 x 23, 32 x 28	1370 – 2990	360 – 1050
Hector[4]	1.6	61 – 217	15 – 30	3000 – 5500	370 – 775
SparsePak[5]	4.7	75 sparse, 17 dense	72 x 71, 39 x 24	1000 – 15,000	380 – 1000
HexPak[6]	1 core, 2.9 annulus	19, 84	6 core, 41 x 36 annulus	1500 – 20,000	380 – 1000
VIRUS–P[7]	4.2	246	102 x 102	~1000	360 – 680
SALT–NIR[8]	1.3	217	21 x 33	2000 – 5200	900 – 1700

[1]Sanchez et al., A&A 538, 8 (2012); [2]Croom et al., MNRAS 421, 872 (2012); [3]Drory et al., AJ 149, 77 (2015); [4]Bryant et al., SPIE 9908, 99081F (2016); [5]Bershady et al., PASP 116, 565 (2004); [6]Wood et al., SPIE 8446, 84462W (2012); [7]Blanc et al., AJ 145, 138 (2013); [8]Wolf et al., SPIE 10702, 107022O (2018).

Currently, the spectrograph is being moved into its cooled enclosure for final assembly and testing, the new collimator optics are being coated and their opto-mechanical mounts are being designed. Fabrication of the 40-metre long fibre cable will begin after testing of the prototype cable is complete, including simulating flexure that the cable will experience through the SALT cable wrap and thermal testing at the –40°C operating temperature of the fibre pseudo-slit feeding the spectrograph. Instrument delivery to SALT is expected in 2020.



NIR spectrum of a Seyfert 2 galaxy, NGC 4388, with a number of lines highlighted that are ionisation and age sensitive, being important for identifying shocks and young stellar populations (GNIRS on Gemini–North; Rodríguez-Ardila et al. 2017).



A laboratory prototype IFU head constructed using a MaNGA-style hexagonal ferrule.

An 8-metre long prototype fibre cable has been constructed to test fabrication techniques and verify performance as a function of different environmental factors. Each individual optical fibre is slid inside a Teflon tube for protection and each of those tubes is held by a shear clamp at the ends of the cable (pictured here).

Software updates

Apart from the usual maintenance and bug fixes, various projects started in 2018 which will come to full fruition in 2019.

Development of a GraphQL-based **application programming interface (API)** for submitting and downloading proposals and blocks, as well as changing the status of blocks, has commenced. While the API and a corresponding Python library will only be released in the first half of 2019, it is already being used successfully through a Python script, putting proposal blocks on and off hold, a task which previously was done manually in the Web Manager.

In order to safeguard the quality of data produced by SALT, a new **data quality site** is being constructed. This site, which will go live in mid-2019, will make it easier to thoroughly monitor data quality in a systematic way.

Specifications for a **data archive** of SALT/SAAO observations have been put together. The aim is to provide easy access to all observations taken by SALT and all other SAAO-operated telescopes at Sutherland. Users will be able to download either non-proprietary observations or observations on which they are an investigator. The archive will offer search filters (e.g., telescope- or instrument-specific filters). The chosen data files can be added to a cart stored in the user's browser. The files in the cart can then be downloaded as a single zip file. Users can be linked to their account(s) for SALT and SAAO telescopes, so that they can be identified as data owner. The archive will be made available by mid-2019.

The improved Fabry–Pérot calibration control on RSS

The Robert Stobie Spectrograph (RSS) has a Fabry–Pérot mode that employs a pair of high-resolution and low-resolution etalons. The etalons are very sensitive to environmental changes and prior to an observing run the instrument must be carefully calibrated for the desired wavelength region. In the years since Fabry–Pérot commissioning, our understanding of the most efficient calibration procedure has improved. Unfortunately, this has also taken a toll on the user interface, with many additions and tweaks. Some controls slipped out of use and other controls were later added to the interface where there was space. The result was an interface that hindered the effective use of the instrument. Early in 2018, it was decided to use our improved understanding to redesign the calibration interface. The new interface (pictured) follows the calibration process steps and allows one to repeat steps; moreover, each etalon now has its own set of controls. An additional improvement had been to move the region settings, which are used for calibration, from text files into a database. This allows for better control over the tables and simplifies the adding of new regions.

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OUTREACH AND EDUCATION

SALT outreach programmes

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OUTREACH AND EDUCATION

SALT COLLATERAL BENEFITS PROGRAMME

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

Science engagement continues to be a driving force for engaging and enthusing individuals. It continues to fuel the passion for which the division coordinates its activities, ensuring maximum outcome for the recipients. The dependence on human, social and economic development being inextricably linked to the development of science and technology has been identified. As in the previous years, the division has exceeded expectation of the yearly science engagement goals by reaching 70,294 people and nurturing its socio economic mandate. This has been realised through the combined efforts of the division with support from fellow colleagues, friends and science communication enthusiasts. 36,423 learners were reached through learner workshops, competitions, career days and exhibitions, 798 teachers were reached through teacher training, support and development workshops, and 33,073 members of the public were reached through exhibitions, public lectures, tours and open nights.

Teacher training

SCBP as a unit is committed to contribute towards improvement and development of teacher quality and classroom practice. The SCBP teacher training programme is geared towards empowering teachers by providing relevant curriculum content, by exposing teachers to innovative pedagogical approaches and by the sharing of modern and creative resources for their classrooms. During this year a total of 798 teachers, drawn from the Western Cape, Northern Cape, KwaZulu–Natal (KZN) and the Limpopo provinces, were trained, developed and supported, as follows.

In collaboration with District of KZN Education Department, a week-long intervention programme was implemented in the Lembe district in May. Target audience was the Senior Phase teachers of Natural Science. A total of 294 teachers were reached through the programme which focused on the theme "Earth and Beyond". Teachers were provided with relevant curriculum content and were informed on creative pedagogical approaches to teaching the astronomy-based theme. This included encouragement and support for naked-eye observations, use of astronomy software such as Stellarium and Celestia, hands-on activities, simulations and investigations. In September, a week-long training, support and development workshop series for teachers was held in KZN, reaching 310 teachers.

In collaboration with the University of Limpopo Science Centre and the Limpopo Provincial Education Department, a week-long programme for Intermediate Phase science teachers was facilitated, reaching 80 teachers. We also collaborated with the Primary Science Project (PSP) and the University of Cape Town's School of Education, where we hosted two one-day workshops, one for 13 PSP teachers and one for 13 postgraduate science education students from UCT. In March, an Astro Quiz presentation for 5 educators was held at Lwandle Primary School in Cape Town.

In collaboration with Eskom Science Expo, a series of one-day workshops were held in Namakwa towns (including Sutherland, Fraserburg, Calvinia, Williston and Springbok), reaching 83 teachers. The objectives of these workshops were to train the teachers on scientific methods and to guide them on how to support learners contesting the Science Expo. Thanks to the SALT Board for providing financial support for the workshops and for the learners' projects.

Learners activities

A total of 36,423 learners were reached through curricular, co-curricular and extra-curricular activities including competitions like the astronomy quiz and the astronomy essay competition, science clubs and career-based activities. Learners were also reached through school visits and participation in science festivals, exhibitions, and stargazing sessions. We also continue to attract learners and schools to visit the Cape Town and the Sutherland Observatory.

Learner workshops and school-based outreach

The purchase of an inflatable planetarium has boosted our efforts at reaching out to historically disadvantaged schools. Increasingly more learners and schools, which have never had the opportunity to visit a planetarium, are being exposed to our inflatable planetarium; the experience serves to inspire learners to appreciate the night sky and the stars by conducting naked-eye observations. The exposure to the inflatable planetarium has also led to requests to the SCBP to host stargazing events using small telescopes at schools.

The SCPB continues to offer "Earth and Beyond" theme-linked workshops based on the topics covered in the school curriculum. These include the Earth–Moon–Sun relationship, phases of the moon, seasons, the solar system, exoplanets, galaxies, telescopes and the historical development of astronomy including indigenous/cultural astronomy knowledge. We further continue to use astronomy as a context for teaching mathematics, physics and chemistry for the higher grades.

The Telescopes in Education project

In 2018, we donated a 6-inch Dobsonian telescope to Kwa Hluz'ingqondo High School in Scottsburg in Southern KwaZulu–Natal. This is part of a continuing effort at ensuring that schools have their own telescope that can be used for astronomy-based learning. We previously have given telescopes to Lwandle Primary School in Khayelitsha, Siyabulela Primary School in Langa Township, Vuselela High School in Worcester and the Ulundi Department of Education District. We are grateful to our sponsors including Christian Hettlage, Rupert De Beer and some medical practitioners who have requested to remain anonymous.

Eskom Science Expo competition

Learners and teachers from the schools in the Namakwa district of the Northern Cape (where Sutherland is situated) were taken through workshops on scientific methods, investigations, research and innovation in preparation for the annual Eskom Science Expo. This exposition is a science fair where learners can show their projects in scientific investigations and win a prize. SAAO was chosen this year as the regional facilitator for the expo in the Namakwa region in August. Black Mountain Vedanta Mine and SALT sponsored the competition. Eleven schools and 122 learners participated in the expo by exhibiting their science-based project. This was a historical and life-changing project for all those who entered the contest by exhibiting their various projects. Awards for the top performers included SALT-sponsored tablets, Eskom Expo smart watches and Black Mountain Vedanta Mine cash prizes. The Grand Prize, for the top two performers, were University of the Western Cape (UWC) Bursaries. SCBP intends to encourage more learners to participate in the Eskom Science Expo in the future. We are grateful to all our partners, Eskom, Department of Education, Black Mountain Vedanta Mine, SAAO and SALT.

Astronomy Quiz

The annual Astronomy Quiz for grade-7 learners remains very popular both in the Western and Northern Cape provinces. The use of the online version of the quiz, introduced a few years ago, continues to make it easier for the rural-based learners and schools to participate. A total of 613 learners from the Western Cape province and 320 learners from Northern Cape province participated in the quiz in June. The provincial winners of the quiz were Park Laerskool from the Western Cape and Postmasburg Primary School in the Northern Cape. Teachers look forward to participating in the quiz as it not only improves the knowledge content, confidence of the learners and their interest in science, but also provides teachers with resources and exposure to modern discoveries and current updates.

Due to the success of the quiz, the Western Cape Education Department made it compulsory in 2017 for all primary schools in the Western Cape to participate in the quiz. The greatest challenge remains the fact that many primary schools use Afrikaans as a medium of instruction, and the quiz is currently only offered in English. Running the quiz online has also inspired a number of organisations to experiment with online science-based competitions, including South Africa's biggest science centre, the Sci–Bono Discovery Centre, and SAASTA who are experimenting with using our code in running a national Science Olympiad.

As part of the price of the Western Cape finals, four learners and their teacher were invited to Sutherland for some stargazing and a day tour.

Robotics clubs and competitions

Luhlaza High School and the Thandokhulu, Langa and Vuyiseka high schools have been introduced to the science and logic of robotics. Through exposure to SCBP-provided kits, they have been able to work on their own chosen projects. Through funding from SAASTA, teams from Langa and Vuyiseka participated in the national robotics competition, and UNISA provided their robotics personnel to support the robotics programme.

Career-based activities

NSTF Brilliants Tour

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

On 28 June, the tour ended with a Gala Dinner for the 20th annual NSTF–South32 Awards at Emperors Palace in Johannesburg in which the Brilliant students were honoured and various other awards for science excellence were given. The awards were presented by the Minister of Science and Technology, Ms Mmamoloko Kubayi–Ngubane, who is the event's patron. The event was attended by almost 700 guests and over 50 different organisations from the broader community. SCBP's manager, Sivuyile Manxoyi, had been one of the nominees for the Communication Award for outreach and creating awareness.

Career exhibitions and expos

In an effort to disseminate information based on astronomy as a career, to share the pathway and the institutions that offer astronomy and to spread information on astronomy opportunities and facilities, SCBP has participated in career exhibitions and expos; a total of 4069 learners were reached this way. The events were held in the Western Cape, Northern Cape and Eastern Cape provinces and included the following exhibitions: the Eskom International Career Expo, Nelson Mandela School of Science and Technology Career exhibition, Mandela Day career activities, King Williamstown Career Exhibition, Dimbaza Career Exhibition and Mdantsane Career Exhibition.

Job shadowing

Two job shadowing sessions were held at SAAO during the June and October school vacations, with 9 and 14 learners, respectively, drawn from various high schools. The holistic programme also highlights related careers and the roles they play in the field of astronomy and thus involves software developers, IT staff, engineers, education and outreach personnel next to astronomers. The two-day intensive programme exposed learners to the experiences of observers as well as theorists; it introduced them to the continuation of observation and data collection through data analysis to interpretation. Furthermore, they received an opportunity to observe and ask questions of the various practitioners. The learners were also supplied with information on the various institutions of higher learning that offer relevant courses, as well as where and when to apply for bursaries and scholarships.

Careers exposition in Namakwa

A 3-day science and technology career-based exposition was held in the Karoo Hoogland region covering the towns of Sutherland, Fraserburg and Williston. The expo created opportunities for Karoo-based learners to interact with representatives from institutions of higher learning as well as having time to converse with professionals from various careers and workplaces. In addition, workshops on computing and programming were facilitated for the youth. We are grateful to SAASTA for providing funding for this event.

Women's Day event

A Women's Day event was held on 9 August 2018, a day celebrated in South Africa as Women's Day. A total of 42 girl learners, drawn from various schools across the Western Cape province, were addressed by female science and technology professionals (from astronomy, software development and space physics among others) representing different careers. The learners had opportunities to interact with the female scientists in an informal way and were able to ask their questions in a more relaxed environment. The learners were also given packs consisting of various brochures and books based on different careers. SALT Observatory Scientist Lisa Crause also gave a talk about astronomical instrumentation for a group of female teachers visiting Sutherland on Women's Day.

Activities for the public

A total of 33,073 members of the public were reached in 2018 through science clubs, science festivals or exhibitions, and tourism at Sutherland Observatory. Open nights and star-gazing events also attracted a great number of people.

Science festivals

In an effort to popularise astronomy and science in general, SCBP continues to participate in national, provincial and regional science festivals. These events give the SCBP team an opportunity to disseminate information about SALT, SAAO, astronomy as a career and science. They also provide platforms to use astronomy to inspire interest in science among learners and general public. SALT remains the draw card and source of inquiries from participants in these festivals. With the building of the radio telescope MeerKAT, SALT has attracted even more inquiries, mainly based on the difference between radio and optical telescopes and also on their locations. Thousands of learners and members of the general public are reached through these festivals. For audiences from outside Western Cape and Northern Cape provinces they also offer an opportunity to interact personally with the Observatory staff.

This year, the SCBP team participated in the Eiding Festival, SciFest, Science Expo, Scitube, the Kirkwood Wild Festival and Scope X. Scope X is an annual astronomy-based science festival usually held in Johannesburg. 2018 was the second year that SAAO had been present at the Kirkwood Wild Festival, which attracted 9560 visitors. The SCBP had an exhibition stand as well as Planetarium shows, which were very popular as they were held in the new portable inflatable planetarium. This year's Science Festival took place in Grahamstown in March. A total of 349 learners between grades 5 and 9 attended workshops on "Solar System and Telescopes" and on "A Hitchhiker's Guide to the Galaxy". The Eiding Science Festival was the most popular this year and attracted over 10,000 visitors, including learners.

National Science Week

South Africa has dedicated the first week of August of every year to celebrate the achievements of science and technology. It is a good time to inspire the youth to decide on science-based studies and to inform the public about the advances made by science and technology in South Africa. One of the main themes of the National Science Week is astronomy and

space science. The SCBP celebrated National Science Week in the Western and Northern Cape provinces. In the Western Cape province, activities were held in Oudtshoorn and Cape Town and in the Northern Cape province, activities were held in Sutherland as well as in the Namakwa area including Springbok and in Postmasburg. Activities included public lectures, learner hands-on activities, Universe awareness activities for young learners and stargazing for the public. A total of 3529 members of the public and 1241 learners were reached during the celebration of the National Science Week.

Science clubs

The SCBP unit continues to encourage the establishment of science clubs across the country. Science clubs are vital in conservation and further development of interest in science inspired by visits to an institution such as SAAO. Over 400 science clubs have been formed to date. SCBP has recently introduced new activities such as the Robotics and Globe project for clubs in the Langa, Phillipi and Khayelitsha townships in Cape Town. Basic introduction to remote telescopes was conducted and applications have been submitted for time with telescopes, such as the Las Cumbres Observatory and MONET, so that science club members can conduct small projects. We are also arranging to apply for time with Lesedi, the new SAAO 1-m telescope in Sutherland.

Open nights at SAAO

Open nights at the Observatory in Cape Town are held every second and fourth Saturday each month, with the exception of December with only one open night on the second Saturday. Thus a total of 23 open nights were held with a total of 1635 people attending in 2018. Open nights include a public lecture, a tour of the SAAO Museum and a stargazing session. Various astronomers from SAAO, UCT, UWC, SARAO as well as visiting astronomers from overseas gave lectures, where the audience ranged from 30 to 160, depending on the topic. The historical McClean Telescope remains the major attraction. It has proven difficult, however, to maintain the telescope due to financial challenges, which means that progress is slow and the work is likely to continue for another year. The open nights have become one of the key attractions to local and international tourists and have made the SAAO site a popular place to visit.

Total lunar eclipse event

The total lunar eclipse stargazing event on 27 July was one of the main attractions in 2018: about 3500 people gathered at the V&A Waterfront in Cape Town to follow the eclipse. SAAO's Science Engagement Astronomer, Daniel Cunnama, and Eddy Nijeboer from ASSA gave educational talks and demonstrations.

Public lectures

In a bid to reach public audiences, various astronomy-based lectures were organised and took place at iThemba LABS, at the Cape University of Technology and at the University of Cape Town. Through the assistance of Dr Christian Hettlage, trial public lectures for the community of Sutherland were given. It is our intention to continue public lectures in collaboration with iThemba LABS and the local universities.

Cultural Astronomy project

The work in the collation and production of the indigenous astronomy knowledge, initiated in 2017, continues. Astronomers and indigenous knowledge holders have been interviewed and footage has been taken at various sites. All the

material will be used in the production of a video that will share the significance of indigenous astronomy knowledge, relate indigenous astronomy to modern astronomy and celebrate the achievement of South African astronomy-based research infrastructure such as SALT and MeerKAT. The video is due to be issued in March 2019.

Tourism

In preparation of the 200-year celebration of the SAAO in 2020, the SAAO Science Engagement team decided to develop a new visitor centre at the SAAO site in Cape Town and to improve Sutherland's visitor centre.

An inaugural Northern Cape Tourism and Education conference was held in Kimberly which sought to bring all tourist facilities, companies involved in tourism as well as education and training centre and tourism teachers together to develop new routes and means of promoting tourism in the Northern Cape. The South African government has identified the Northern Cape as the Astronomy Hub of South Africa, and SALT has emerged as an ace of tourism, attracting visitors to the Northern Cape including overseas tourists. At the conference, the SCBP manager presented a paper entitled "SALT as an ace of astro–tourism in SA" which highlighted the growth of tourism in the Karoo Hoogland Area, where SALT is located, since the construction of the telescope. A new astro–tourism route in the Northern Cape province is now being developed, involving, among many partners, SAAO, the Department of Science and Technology and the Department of Tourism.

Two learners and a teacher from Carnarvon near the MeerKAT site won a national tourism competition. Their essay was based on the huge impact that SALT has had on tourism in the Northern Cape.

Sutherland activities

Visitor centre

The Sutherland Tours remain very popular; in 2018, 10,473 people visited Sutherland. Specific astronomical events always spur interest and encourage people to visit Sutherland. We also advertise in various tourist magazines and on websites, and SALT is one of the greatest attractions for people to visit the Northern Cape province. We are continuously promoting astro–tourism in Sutherland, and tourism continues to contribute to the socio-economic development in the village by way of jobs for the youth of Sutherland and surrounding areas. Training for new tour guides was provided in conjunction with the Centre for Astronomical Heritage.

Community Development Centre

The Community Development Centre continues to serve as a rallying point of development in the community of Sutherland and to facilitate improvement of the socio-economic well-being of the town of Sutherland. Various activities have been conducted all through the year. For example, SCBP facilitated an 8-month course in construction for 20 unemployed matriculants.

On Youth Day, a South African holiday celebrated on 16 June, the SCBP staff collaborated with other local stakeholders from Sutherland to organise a sports day for the youth. During this event all stakeholders were given the opportunity to engage with the youth on career opportunities at various institutions; they were also reminded why we celebrate this day in South Africa.

During Mandela Day on 18 July, the SCPB collaborated with various local stakeholders to donate paint to Roggeveld Primary School, 20 combined desks to Roggeveld Primary school, 10 blankets to the Sutherland Old Age Home, and sanitary bins to both schools as well as the clinic. Later in the day's program, the SCBP staff were joined by the SAAO's Telescope Operations department to give soup and bread to the children and patients at the Sutherland clinic.

Minister Patel's visit

Minister Patel visited Sutherland on 29 October 2018 to bring together all government agencies that could assist local entrepreneurs. This SSME (Small Medium Micro Enterprises) Imbizo (forum for discussion) was the second after the original 2016 Imbizo, which was initiated by the minister's request to provide the local entrepreneurs with access to government agencies and was also held in Sutherland and hosted by the Department of Economic Development. This year's objective was to ensure that the entrepreneurs are fully compliant and thus able to access the offered opportunities for business. The Imbizo was attended by over 50 local entrepreneurs and government agencies such as the Small Enterprise Development Agency (SEDA), the Small Enterprise Finance Agency (SEFA), the Northern Cape Provincial Department of Tourism, the South African Revenue Service (SARS) and many more. SAAO/NRF and SALT were part of ten selected entities that were invited. The team reported on progress in leveraging tourist attractions to promote local business at the observatory and progress of local procurement to local business in Sutherland. Some of the objectives addressed therein by the department of Economic Development included establishment of business development plans, business coaching and mentoring and market access.

During his visit, Minister Patel also formally handed over the upgraded Sneeuvlokkie (`Snowflake') childcare centre to the community at large. The upgrade included additional classrooms, restoration to infrastructure, educational material and training for all early childhood practitioners.

Take a girl child to work

A special inaugural and very successful event was implemented in Sutherland, dubbed a "Take a Girl Child to Work" event. Fourteen girl learners from the village spent a day at the Sutherland Observatory with the opportunity to observe and interact with various professionals including astronomers, engineers, technicians, IT specialists and administrative and outreach professionals. The feedback from the participants was positive, and we intend to run this programme quarterly.

Word of Gratitude and acknowledgement

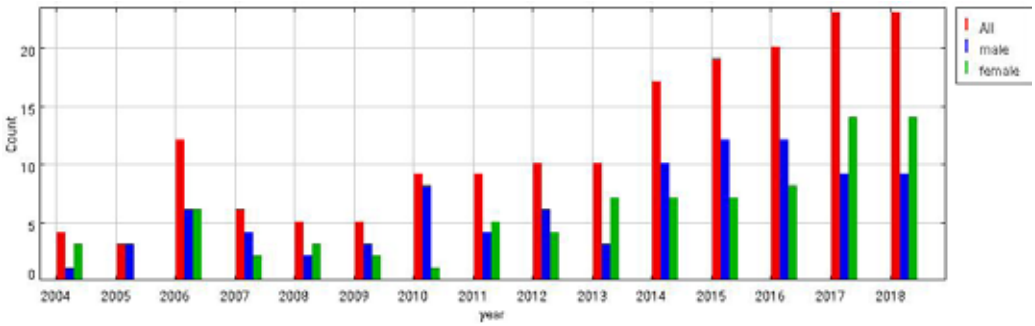
We would like thank our SALT partners for all their assistance in the execution of education and outreach programmes. We would also like to thank the SAAO executive and the Director, Professor Petri Väisänen, for the support of the science engagement programmes. We wish to extend a word of gratitude to all SCBP staff members for their contributions and hard work that has made this year a success and to all our post-graduate students who always avail themselves. Special thanks to Dr Christian Hettlage.

SCBP HIGHLIGHT: JOB SHADOWING – A SUCCESS STORY

While job shadowing has always been conducted and supported at SAAO, it used to be the shadowing of an astronomer only. When the numbers of requests started to increase in 2014 (and also to relieve the workload to the individual astronomer of taking care of a learner for a full two days), Natalie Jones, Information and Resources Officer at SCBP, undertook to design and implement a new programme. She proposed to give the learners an opportunity to make informed career choices by exposing them to multiple careers at SAAO, from research in astronomy and instrumentation, through mechanical engineering and electronics, information technology and software engineering, to finance and library work. The learners would also be informed about available bursaries, as well as given HR-related information, aimed at giving them an idea of what they could be earning in those particular careers.

This new job shadow programme was set in motion in July 2014 and immediately became a great success: requests to come to SAAO multiplied. In July 2017, Natalie introduced a new section to the programme covering a 'view from a student's perspective' where learners get the opportunity to speak to Ph.D. students working at SAAO. They are closer in age to the learners and best suited to answer the real questions of what university life is all about, the pro's and the con's, and what it takes to be successful.

Between August 2004 and October 2018, a total of 175 learners have been reached through the job shadow programme at SAAO (with roughly an equal split between male and female learners, see figure), where 101 of them came after the inception of this new programme in 2014. In feedback forms, learners have marked their overall job shadow experience at the SAAO as excellent. More information can be found on the SAAO website under the "About" menu.



SALT PARTNERS: UKSC AND IUCAA ACTIVITIES

The University of Southampton, partner in the UK SALT Consortium, together with IUCAA, initiated the Southampton–IUCAA Training for Astronomical Research and Education (SITARE) programme (April 2018 – May 2019) to nurture future research stars across the Indian sub-continent (including Nepal) through astronomy. The programme focuses on astronomy and astrophysics education and research activities as a means to encourage Masters' level university students to pursue higher level research. The students are taught transferable skills in data analysis and critical thinking which will allow them to apply their knowledge beyond astronomy. The programme includes a series of workshops in four geographical regions of India and one in Nepal, targeting ~80 students per region. Apart from lectures in modern astrophysics and data science, one-on-one sessions are held with students so as to provide encouragement and to answer their queries on career directions and possibilities. Selected students from the first set of workshops went on to participate in a longer, more advanced training camp at IUCAA, following which, 8 students were chosen for the final event to be held at Southampton University. There they will carry out a short research project under local supervision to give them exposure to the international astronomical facilities now becoming available. During his participation in one of the SITARE workshops in India last year, Phil Charles from Southampton University gave a talk in Pune to the local astronomical society entitled "The Story of SALT: Africa's 'low-cost' very large telescope".

Assam workshop at the University of Tezpur: SITARE workshop students together with Phil Charles (UKSC), Ranjeev Misra and Ajit Kembhavi (IUCAA).

Visiting SALT

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OUTREACH AND EDUCATION

DELEGATIONS AND VISITS

In 2018, the following parties visited SALT at Sutherland.

14 – 15 July 2018

Derek Hanekom – Minister of Parliament, Travel and Tourism
Mrs Hanekom
Melanie Titus
Ansley Hendriks – Protector
Lucas Mlandezwa – Protector

On his return from the launch of the MeerKAT radio telescope near Carnarvon, Minister Hanekom and his group spent the night of 14 July 2018 at the SAAO hostel Sutherland. He and his people used the opportunity to visit SALT as well as the Community Centre in the village.

10 – 13 September 2018

University of Cape Town students

Approximately 85 first-year science students from the University of Cape Town's Extended Degree Programme (EDP) visited Sutherland on their Science Odyssey tour, organised by Assistant Dean David Gammon. The students stayed in the hotel in town for two nights each and came up to the telescopes for afternoon tours in groups of ~20/day, Monday to Thursday. They also came up on the Tuesday and Thursday evenings in groups of 40+ for night tours. The day tour included a walk around the plateau with visits to Lesedi, the 1.9-m and SALT, while the night tour involved exploring the visitor centre and viewing a number of planets, the moon and some clusters through the visitor telescopes. The timing was excellent as the night sky was particularly spectacular at the time, with the centre of the Milky Way directly overhead, as well as Venus, Jupiter, Saturn and Mars on display. The thin crescent moon was beautiful through a telescope too and then once it set, stargazers were left to enjoy the stunning dark night sky with its numerous celestial treasures. The Science Odyssey coincided with the 14 third-year Astronomy students from UCT learning how to observe galaxies in the Zone of Avoidance with the SpUpNIC spectrograph on the 1.9-m telescope. That weekend, the third-years were joined by the second-year Astronomy students (also from UCT) for a brief visit. This was the third instalment of the Science Odyssey, with twice as many students involved this year than previously and the event now seems set to remain a highlight on the EDP calendar. The tours were led by Lisa Crause, with assistance from Pranesthan Govender and Delshia Kamfer from the SCBP team, and SALT Tech Ops staff were on hand to move the structure and dome to add to the excitement of the SALT visits.

29 October 2018

Ebrahim Patel – Minister of Parliament, Economic Development
Aldene Appolis – Chief of Staff
Molefe Itumeleng Pule – Deputy Director General
Brian Zondo – Director Development Finance Institutions

Minister for Economic Development, Honourable Ebrahim Patel, hosted an Entrepreneurial Imbizo (gathering) at Sutherland in October. Following the Imbizo, the Minister and his delegation spent the evening in hospitality offered by the SAAO, followed by an evening tour of SALT by SALT Astronomer Marissa Kotze and a tour of the Visitor Centre, including a stargazing session with Pranesthan Govender and Anthony Mietas. The Minister expressed his sincere gratitude and stated that he looked forward to his future visits.

MP Ebrahim Patel with SCPB officer Anthony Mietas at the observatory hostel.

MEDIA VISITS TO SALT

7 – 9 February 2018: Japanese National Observatory

Max Safari, from Max Contact Co. Ltd, has been commissioned by the Japanese National Observatory to do a story on all South African based telescopes that were involved in the first gravitational wave multi-messenger observations of GrW170817. He also interviewed the astronomers that were involved in the observations. Patrick Woudt from UCT (Co–PI of MeerLICHT) was interviewed inside the Japanese facility IRSF. The SALT part of the film was covered by David Buckley (standing in for Petri Väisänen) from SAAO. The film will be shown to a Japanese audience who are interested in the mystery of the Universe and the Japanese Observatory from a young age.

14 – 15 April 2018: Martin Ratcliffe Photography

Martin Ratcliffe, representing Sky-Skan (a company that designs and installs full-dome planetariums and visualisation theaters), spent ~ 1 – 2 nights doing photography outside SALT and the small telescopes, as well as inside SALT. He used a wide-angle tracking DSLR camera, sensitive to Hα, for Milky Way shots with domes in the foreground. He took still images for personal use and to share with the Iziko Planetarium in Cape Town.

7 September 2018: Perfect Timing Photography Tours

Perfect Timing Photography Tours is a spinoff of Cape Photographic Company, which runs annual photographic workshops that teach participants the art of taking star trails and Milky Way photographs. Steff Hughes brought a group of amateur photographers to Sutherland to take photos of SALT in the evening. Their aim was to film the exterior of the telescopes with SALT as the focal point. Photos were taken for personal use and on occasion may be shown to a photographic club.

21 September 2018: 5FM radio station

Being a country of diversity, South Africa celebrates Heritage Day on 21 September as a national holiday to encourage all South Africans to honour their culture and the diversity of their beliefs and traditions. 5FM radio disk jockey Nick Hammond and producer Michael Bossenger decided to celebrate a full Heritage Month this year. They took great pleasure in exploring the country, spending at least two days travelling each of South Africa's nine provinces, visiting special sites and linking them to their tour. 5FM listeners had the opportunity of tuning in and being taken along on this informative journey.

The Northern Cape province has many special sites, and a visit to SALT is always considered a memorable experience for travelers and tourists alike. Lisa Crause and Pranesthan Govender gave Nick and Mike a behind-the-scenes tour of SALT which left them amazed at this 'engineering marvel'. Lisa also attended their show, answering questions regarding astronomy in general and SALT in particular. The interview was followed by an evening of stargazing. Nick and Mike, being impressed by SALT and the experience of the stargazing, got involved in conversations about astronomy and space well into the early hours of the morning. The captivating broadcast of the tour, which many South Africans had the opportunity to listen to, created wide-spread exposure for SALT and the Northern Cape.

VISITING SALT PARTNERS

During the course of the year, NRF Deputy CEO Dr Clifford Nxomami and SAAO Director Petri Väisänen paid visits to the various SALT partners. At each of the partner institutes they met both astronomers as well as the funding principals and administration of the different organisations. The purpose of the visits was to share the latest SALT updates, especially regarding the SALT Generation 1.5 project, and to discuss options for future funding models. The itinerary was as follows:

May: Dartmouth College, Rutgers University, University of North Carolina
June: UK SALT partners
October: Poland and IUCAA
Online meetings: UW and AMNH

In addition, Nxomami and Väisänen made official visits promoting SALT to several institutes in Moscow, Russia, in May, and the Indian Institute of Astrophysics in Bangalore, India, in October.

NOBEL-INSPIRED LECTURE

As part of the Swedish–South Africa Nobel-inspired lecture series, the National Research Foundation hosted the lecture "Discovery of Gravitational Waves – What it means for future science" by the Director of the SAAO, Prof. Petri Väisänen, on 2 October 2018 at SAAO. Väisänen is an NRF-rated astronomer with extensive experience in different observational and data reduction and analysis methods across multiple wavelength regions and multiple observatories. He is internationally recognised and enjoys membership of many international organisations such as the International Astronomical Union, and the International Society of Optics and Photonics.

As a SALT Astronomer, Väisänen was part of the international team of scientists that carried out unprecedented electromagnetic follow-up observations soon after a neutron star merger event triggered gravitational wave detections. SALT was one of the first telescopes to obtain spectroscopic data of the light from this explosion. The lecture explored what this new find means for the development of Big Science and the future of Multi-Messenger Astronomy in South Africa.

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

Dignitaries included:

Dr Beverley Damonse – Group Executive: Science Engagement and Corporate Relations, NRF
HE Ms. Cecilia Julin – Ambassador, Embassy of Sweden in Pretoria
Dr Molapo Qhobela – CEO, NRF
Mr. Olof Somell – Curator, Nobel Museum in Sweden

The lecture was positively received judging by the comments and the discussions it initiated in social media.

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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. Gerald Cecil
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
National Research Foundation, South Africa

Prof. John P. Hughes
Rutgers University, USA

Dr Molapo Qhobela
National Research Foundation, South Africa

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

Prof. Marek Sarna
Nicolaus Copernicus Astronomical Centre, Poland

Prof. Eric Wilcots
University of Wisconsin–Madison, USA

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

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

Operations contract

SALT is operated on behalf of the SALT Foundation by the 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 Chris Coetzee, 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 typically meets once 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 four Board members. In this reporting period, they were: Prof. Mike Shara (Chair), Prof. Brian Chaboyer, Prof. Eric Wilcots and Prof. Phil Charles.

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. E. Wilcots (Chair), Prof. G. Bromage, Prof. J. Hughes 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 of the STC were: Paul Groot, Matt Bershady, Hermine Schnetler, John Booth, Joanna Mikołajewska, David Buckley and Lisa Crause (Chair).

Technical Operations Team 2018

Chris Coetzee (Head)

Richard Banda*
Janus Brink
Keith Browne
Alrin Christians*
Lisa Crause*
Willa de Water
Timothy Fransman
Denville Gibbons
Johan Hendricks
Stephen Hulme
Nicolaas Jacobs
Anthony Koeslag
Jonathan Love
Deneys Maartens
Thabelo Makananise
Adelaide Malan
Paul Rabe
Etienne Simon
Ockert Strydom
Mark Wichman*
Eben Wiid

Astronomy Operations Team 2018

Encarni Romero Colmenero (Head)

Steve Crawford*
Éric Depagne
Danièl Groenewald*
Christian Hettlage
Alexei Kniazev
Thea Koen
Marissa Kotze
Rudi Kuhn
Nhlavutelo Macebele
Fred Marang*
Anelisiwe Mayekiso*
Brent Miszalski
Moses Mogotsi*
Itumeleng Monageng*
Sifiso Myeza
Rajin Ramphul*
Anja Schröder
Rosalind Skelton
Veronica van Wyk

SALT Observatory Scientist

Lisa Crause*

Corporate Governance Team 2018

Lizette Labuschagne
Surayda Moosa

* part-time and/or part of the year

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PUBLICATIONS

REFEREED PUBLICATIONS*

Amvrosiadis, A., Eales, S. A., Negrello, M., et al. 2018, MNRAS, 475, 4939
Aydi, E., Orio, M., Beardmore, A. P., et al. 2018, MNRAS, 480, 572
Aydi, E., Page, K. L., Kuin, N. P. M., et al. 2018, MNRAS, 474, 2679
Baglio, M. C., Russell, D. M., Casella, P., et al. 2018, ApJ, 867, 114
Buckley, D. A. H., Andreoni, I., Barway, S., et al. 2018, MNRAS, 474, L71
Cracco, V., Orio, M., Ciroi, S., et al. 2018, ApJ, 862, 167
Dutta, R., Srianand, R., and Gupta, N. 2018, MNRAS, 480, 947
Dye, S., Furlanetto, C., Dunne, L., et al. 2018, MNRAS, 476, 4383
Foley, R. J., Scolnic, D., Rest, A., et al. 2018, MNRAS, 475, 193
Glikman, E., Lacy, M., LaMassa, S., et al. 2018, ApJ, 861, 37
González-Galán, A., Oskinova, L. M., Popov, S. B., et al. 2018, MNRAS, 475, 2809
Grady, C. A., Brown, A., Welsh, B., et al. 2018, AJ, 155, 242
Gull, M., Frebel, A., Cain, M. G., et al. 2018, ApJ, 862, 174
Gvaramadze, V. V., Alexashov, D. B., Katushkina, O. A., et al. 2018, MNRAS, 474, 4421
Gvaramadze, V. V., Kniazev, A. Y., Maryeva, O. V., et al. 2018, MNRAS, 474, 1412
Hema, B. P., Pandey, G., and Srianand, R. 2018, ApJ, 864, 121
Hilton, M., Hasselfield, M., Sifón, C., et al. 2018, ApJs, 235, 20
Holdsworth, D. L., Kurtz, D. W., Saio, H., et al. 2018, MNRAS, 473, 91
Holdsworth, D. L., Saio, H., Bowman, D. M., et al. 2018, MNRAS, 476, 601
Hood, C. E., Kannappan, S. J., Stark, D. V., et al. 2018, ApJ, 857, 144
Hovey, L., Hughes, J. P., McCully, C., et al. 2018, ApJ, 862, 148
Hviding, R. E., Hickox, R. C., Hainline, K. N., et al. 2018, MNRAS, 474, 1955
Iłkiewicz, K., Mikołajewska, J., Miszalski, B., at al. 2018, MNRAS, 476, 260
IceCube Collaboration, Aartsen, M. G., Ackermann, M., et al. 2018, Science, 361, eaat1378
Karim, M. T., Fox, A. J., Jenkins, E. B., et al. 2018, ApJ, 860, 98
Kilic, M., Hermes, J. J., Córsico, A. H., et al. 2018, MNRAS, 479, 1267
Kniazev, A. Y., Egorova, E. S., and Pustilnik, S. A. 2018, MNRAS, 479, 3842
Kollatschny, W., Ochmann, M. W., Zetzl, M., et al. 2018, A&A, 619, A168
Maxted, P. F. L. and Hutcheon, R. J. 2018, A&A, 616, A38
Miszalski, B., Manick, R., Mikołajewska, J., et al. 2018, MNRAS, 473, 2275 [Erratum: MNRAS, 474, 646]
Miszalski, B., Manick, R., Mikołajewska, J., et al. 2018, PASA, 35, e027
Mitchell, C. J., Sellwood, J. A., Williams, T. B., et al. 2018, AJ, 155, 123
Mosby, G., Indahl, B., Eggen, N., et al. 2018, JATIS, 4, 014001
O'Malley, E. M., and Chaboyer, B. 2018, ApJ, 856, 130
Reeve, D. and Howarth, I. D. 2018, MNRAS, 478, 3133
Sako, M., Bassett, B., Becker, A. C., et al. 2018, PASP, 130, 064002
Shen, K. J., Boubert, D., Gänsicke, B. T., et al. 2018, ApJ, 865, 15
Stiele, H. and Kong, A. K. H. 2018, ApJ, 852, 34
Tartaglia, L., Sand, D. J., Valenti, S., et al. 2018, ApJ, 853, 62
Vaghmare, K., Barway, S., Väisänen, P., et al. 2018, MNRAS, 480, 4931
van Jaarsveld, N., Buckley, D. A. H., McBride, V. A., et al. 2018, MNRAS, 475, 3253
Vanbeveren, D., Mennekens, N., Shara, M. M., et al. 2018, A&A, 615, A65

* Publications in ISI approved journals with data or information from, or related to, SALT

Vivek, M., Srianand, R., and Dawson, K. S. 2018, MNRAS, 481, 5570
Zemko, P., Ciroi, S., Orio, M., et al. 2018, MNRAS, 480, 4489
Zetzl, M., Kollatschny, W., Ochmann, M. W., et al. 2018, A&A, 618, A83

OTHER SALT PUBLICATIONS**

Telegrams and notices

Arcavi, I., Gromadzki, M., Wyrzykowski, L., et al. 2018, The Astronomer's Telegram, 11363
Aydi, E., Buckley, D. A. H., Chomiuk, L., et al. 2018, The Astronomer's Telegram, 12311
Aydi, E., Buckley, D. A. H., Mohamed, S., et al. 2018, The Astronomer's Telegram, 11684
Aydi, E., Buckley, D. A. H., Mohamed, S., et al. 2018, The Astronomer's Telegram, 11287
Aydi, E., Buckley, D. A. H., Mohamed, S., et al. 2018, The Astronomer's Telegram, 11290
Aydi, E., Buckley, D. A. H., Mohamed, S., et al. 2018, The Astronomer's Telegram, 11338
Aydi, E., Buckley, D. A. H., Mohamed, S., et al. 2018, The Astronomer's Telegram, 11364
Aydi, E., Buckley, D. A. H., Mohamed, S., et al. 2018, The Astronomer's Telegram, 11221
Aydi, E., Buckley, D. A. H., Mohamed, S., et al. 2018, The Astronomer's Telegram, 11607
Aydi, E., Chomiuk, L., Strader, J., et al. 2018, The Astronomer's Telegram, 11878
Bose, S., Dong, S., Chen, P., et al. 2018, The Astronomer's Telegram, 12246
Bose, S., Dong, S., Gromadzki, M., et al. 2018, The Astronomer's Telegram, 12137
Buckley, D. A. H., Gromadzki, M., Dong, S., et al. 2018, Transient Name Server Classification Report, 1253
Buckley, D. A. H., Gromadzki, M., Dong, S., et al. 2018, The Astronomer's Telegram, 11993
Buckley, D. A. H., Gromadzki, M., Dong, S., et al. 2018, The Astronomer's Telegram, 11695
Buckley, D. A. H., Gromadzki, M., Dong, S., et al. 2018, The Astronomer's Telegram, 11712
Buckley, D. A. H., Gromadzski, M., Gorbovskoy, E., et al. 2018, The Astronomer's Telegram, 12343
Buckley, D. A. H., Potter, S. B., Lipunov, V., et al. 2018, The Astronomer's Telegram, 11897
Coe, M. J., Kennea, J. A., Buckley, D., et al. 2018, The Astronomer's Telegram, 12229
Dong, S., Gromadzki, M., Buckley, D. A. H., et al. 2018, Transient Name Server Classification Report, 813
Dong, S., Prieto, J. L., Buckley, D. A. H., et al. 2018, The Astronomer's Telegram, 11346
Eweis, Y., Jha, S. W., Camacho, Y., et al. 2018, The Astronomer's Telegram, 11980
Gromadzki, M., Wyrzykowski, L., and Buckley, D. A. H. 2018, The Astronomer's Telegram, 11128
Ihanec, N., Gromadzki, M., Wyrzykowski, L., et al. 2018, The Astronomer's Telegram, 11291
Jha, S. W., Camacho, Y., Dai, M., et al. 2018, The Astronomer's Telegram, 11777
Jha, S. W., Camacho-Neves, Y., Dai, M., et al. 2018, The Astronomer's Telegram, 12122
Kammers, R., Ferreira, T. S., Saito, R. K., et al. 2018, The Astronomer's Telegram, 11365
Sokolovsky, K., Gromadzki, M., Wyrzykowski, L., et al. 2018, The Astronomer's Telegram, 11709
Sokolovsky, K., Gromadzki, M., Wyrzykowski, L., et al. 2018, The Astronomer's Telegram, 11434
Wyrzykowski, L., Gromadzki, S., Kozlowski, M., et al. 2018, The Astronomer's Telegram, 11716

** not complete

Published conference proceedings

Arentsen, A., Starkenburg, E., Shetrone, M. D., et al. 2018, Rediscovering Our Galaxy, Proc. IAU Symposium, 334, 273

Aydi, E. 2018, 42nd COSPAR Scientific Assembly, 42, E1.7-32-18

Booth, J. A. and Crause, L. A. 2018, Modeling, Systems Engineering, and Project Management for Astronomy VIII, Proc. SPIE, 10705, 1070509

Booth, J. A., Shara, M., Crawford, S. M., et al. 2018, Ground-based and Airborne Telescopes VII, Proc. SPIE, 10700, 107000S

Brink, J. D., Strydom, O. J., Hulme, S. N., et al. 2018, Advances in Optical and Mechanical Technologies for Telescopes and Instrumentation III, Proc. SPIE, 10706, 1070668

Brink, J. D., Strydom, O. J., Pretorius, M. L., et al. 2018, Advances in Optical and Mechanical Technologies for Telescopes and Instrumentation III, Proc. SPIE, 10706, 107066H

Browne, K. R. J. and Hettlage, C. 2018, Observatory Operations: Strategies, Processes, and Systems VII, Proc. SPIE, 10704, 1070423

Charles, P., Maccarone, T., Dewangan, G. C., et al. 2018, 42nd COSPAR Scientific Assembly, 42, E1.7-30-18

Coetzee, J. C., Shara, M., Williams, T. B., et al. 2018, Observatory Operations: Strategies, Processes, and Systems VII, Proc. SPIE, 10704, 107040P

Crause, L. A., Butler, R. P., Nave, G., et al. 2018, Ground-based and Airborne Instrumentation for Astronomy VII, Proc. SPIE, 10702, 107025S

Czerny, B., Sredzinska, J., Kotlarz, J., et al. 2018, XXXVIII Polish Astronomical Society Meeting, 7, 267

Dambis, A. K., Berdnikov, L. N., Rastorguev, A. S., et al. 2018, Modern Star Astronomy, XIII Congress of the International Public Organization "Astronomical Society", 1, 144

Fullard, A., Ansary, Z., Azancot Luchtan, D., et al. 2018, American Astronomical Society Meeting Abstracts, 232, 315.03

Fullard, A. G., Hoffman, J. L., DeKlotz, S., et al. 2018, RNAAS, 2, 37

Gromadzki, M., Wyrzykowski, L., Hamanowicz, A., et al. 2018, XXXVIII Polish Astronomical Society Meeting, 7, 193

Hettlage, C., Romero Colmenero, E., Crawford, S., et al. 2018, Observatory Operations: Strategies, Processes, and Systems VII, Proc. SPIE, 10704, 107042D

Hulme, S. N., Maartens, D. S., Brink, J. D., et al. 2018, Software and Cyberinfrastructure for Astronomy V, Proc. SPIE, 10707, 107072N

Koeslag, A. R., Brink, J. D., Hulme, S. N., et al. 2018, Software and Cyberinfrastructure for Astronomy V, Proc. SPIE, 10707, 107072M

Love, J., Coetzee, J. C., Gajjar, H., et al. 2018, Observatory Operations: Strategies, Processes, and Systems VII, Proc. SPIE, 10704, 1070425

Maartens, D. S. and Brink, J. D. 2018, Software and Cyberinfrastructure for Astronomy V, Proc. SPIE, 10707, 107070E

Rabe, P., Browne, K. R., Wiid, E., et al. 2018, Ground-based and Airborne Telescopes VII, Proc. SPIE, 10700, 1070006

Romero-Colmenero, E., Väisänen, P., Williams, T., et al. 2018, Observatory Operations: Strategies, Processes, and Systems VII, Proc. SPIE, 10704, 107040O

Castro Segura, N. and Knigge, C. 2018, 42nd COSPAR Scientific Assembly, 42, E1.7-8-18

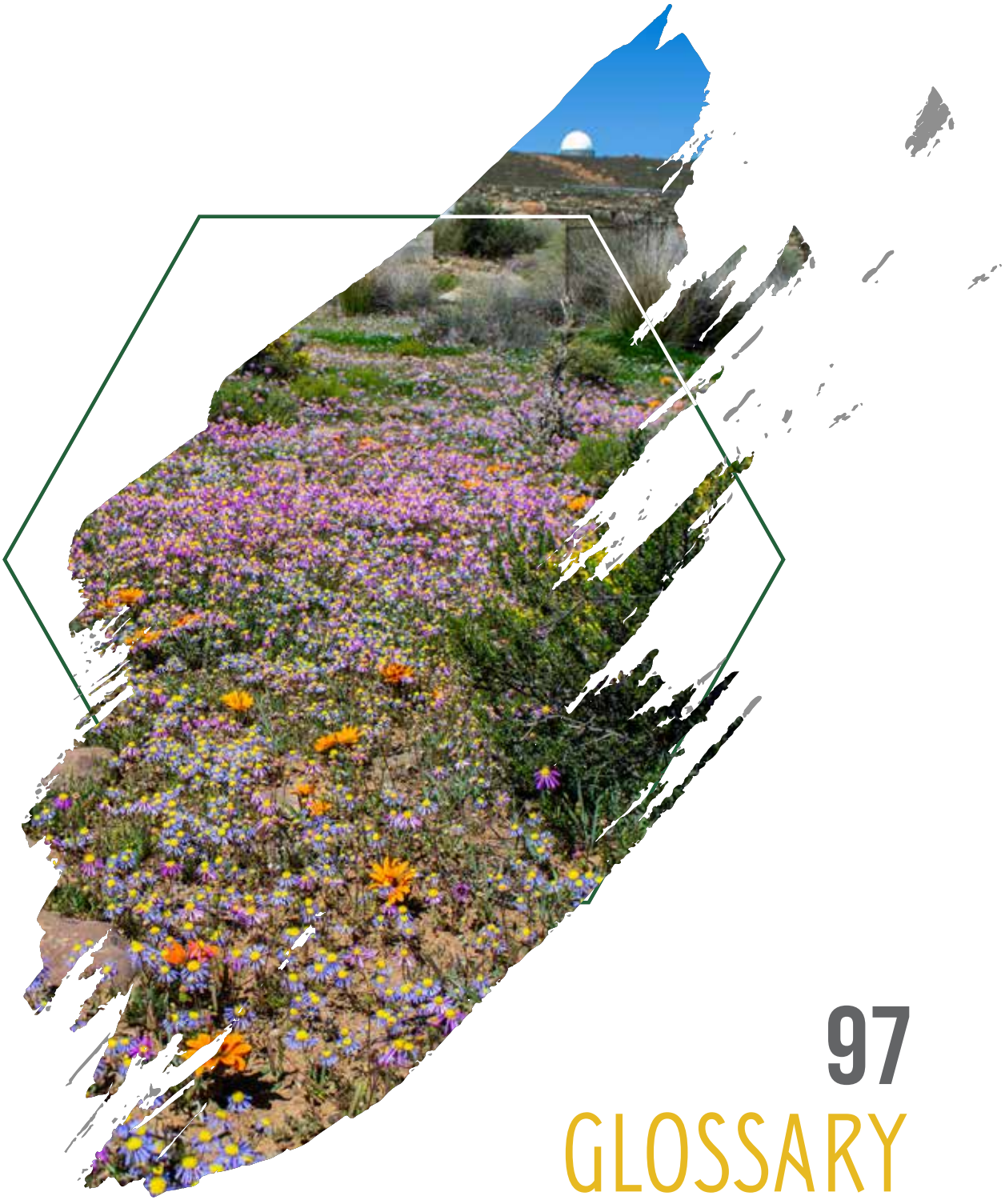
Simon, E. L., Coetzee, J. C., Browne, K. R. J., et al. 2018, Observatory Operations: Strategies, Processes, and Systems VII, Proc. SPIE, 10704, 1070424

Smith, M. P., Wolf, M. J., Bershady, M. A., et al. 2018, Ground-based and Airborne Instrumentation for Astronomy VII, Proc. SPIE, 10702, 107023C

Väisänen, P., Crause, L., Gilbank, D., et al. 2018, Observatory Operations: Strategies, Processes, and Systems VII, Proc. SPIE, 10704, 107040A

Wiid, E. P., Browne, K., Love, J. J., et al. 2018, Observatory Operations: Strategies, Processes, and Systems VII, Proc. SPIE, 10704, 1070429

Wolf, M. J., Adler, D. P., Bershady, M. A., et al. 2018, Ground-based and Airborne Instrumentation for Astronomy VII, Proc. SPIE, 10702, 107022O



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GLOSSARY AND ACRONYMS

GLOSSARY AND ACRONYMS

2D	two dimensional
3D	three dimensional
ACT	Atacama Cosmology Telescope
ADAF	advection dominated accretion flow
AGB	asymptotic giant branch
AGN	active galactic nucleus
AMNH	American Museum of Natural History
API	application programming interface
ASASSN	All Sky Automated Survey for SuperNovae
ASIC	Application Specific Integrated Circuit
ASSA	Astronomical Society of South Africa
AU	astronomical unit
BAL	broad absorption line
BEC	board executive committee
BLR	broad line region
BPT	Baldwin, Phillips & Terlevich 1981
BTA	Big Azimuthal Telescope
BVIT	Berkeley Visible Image Tube camera
CALIFA	Calar Alto Legacy Integral Field Area spectrograph
CAMK	Nicolaus Copernicus Astronomical Center
CCD	charge-coupled device
CCF	cross-correlation function
CDM	cold dark matter
CDS	correlated double sample
CE	common-envelope
CEO	chief executive officer
CFO	chief financial officer
CHILES	COSMOS HI Large Extragalactic Survey
CL	cluster
CNO	Carbon–Nitrogen–Oxygen
Co–I	co–investigator
COSMOS	COSMOlogical evolution Survey
CTA	Cherenkov Telescope Array
CTIO	Cerro Tololo Inter–American Observatory
D6	dynamically driven double-degenerate double-detonation
DC	Dartmouth College
DDT	director's discretionary time
DR	data release
DSLR	digital single lens reflex camera
DST	Department of Science and Technology
EDP	Extended Degree Programme
ESA	European Space Agency
ESO	European Southern Observatories
FAC	finance & audit committee
FIR	far-infrared
FORS2	FOcal Reducer/low dispersion Spectrograph 2
FP	Fabry–Pérot
FWHM	full width half maximum
GATS	Global Astrophysical Telescope System
Gen	generation
GMRT	Giant Metrewave Radio Telescope
GNIRS	Gemini Near-InfraRed Spectrograph
GW	gravitational wave
GWP	gravitational wave programme
H2RG	HAWAII–2RG detector
HD	Henry Draper
HE	Hamburg–ESO survey
HERMES	High-Efficiency and high-Resolution Mercator Echelle Spectrograph
H.E.S.S.	High Energy Stereoscopic System
HET	Hobby–Eberly Telescope
HMXB	high-mass X-ray binary
HR	high-resolution (Fabry–Pérot)
HR	human resources
HRS	high-resolution spectrograph
HS	high-stability (HRS)
HST	Hubble Space Telescope
IAO	Institute Astronomical Observatory
IFS	integral field spectrograph
IFU	integral field unit
INT	Isaac Newton Telescope
IR	infrared
IRSF	InfraRed Survey Facility
ISDEC	IUCAA SIDECAR Drive Electronics Controller
ISI	international scientific indexing
ISM	interstellar medium
IT	information technology
IUCAA	Inter–University Centre for Astronomy & Astrophysics
KAT	Karoo Array Telescope
KZN	KwaZulu–Natal
LADUMA	Looking At the Distant Universe with the MeerKAT Array
LBV	luminous blue variable
LCO	Las Cumbres Observatory
LIGO	Laser Interferometer Gravitational Wave Observatory
LMC	Large Magellanic Cloud
LOFAR	LOw Frequency ARray
LR	low-resolution (Fabry–Pérot)
LSP	large science programme
LSST	Large Synoptic Survey Telescope

MaNGA	Mapping Nearby Galaxies at Apache Point Observatory
MASTER	Mobile Astronomical System of the TElescope–Robots network
MaxE	Maximum Efficiency spectrograph
MAXI	Monitor of All-sky X-ray Image
MDM Observatory	Michigan–Dartmouth–MIT Observatory
MIDAS	Munich Image Data Analysis System
MILES	Medium resolution INT Library of Empirical Spectra
MJD	modified Julian Date
MONET	MOnitoring NEtwork of Telescopes
MOS	multi-object spectrograph
MR	medium resolution
NASA	National Aeronautics and Space Administration
NCAC	Nicolaus Copernicus Astronomical Center
NEMA	National Electrical Manufacturers Association
NGC	New General Catalog
NIR	near-infrared
NRF	National Research Foundation
NSTF	National Science and Technology Forum
NWU	North–West University
OGLE	Optical Gravitational Lensing Experiment
P0 … P4	priority 0 – 4
PAS	Polish Academy of Sciences
PFGS	Prime Focus Guidance System
PI	principal investigator
PN	planetary nebula
POL	Poland
PSP	Primary Science Project
PyHRS	Python package for HRS data reduction
rad	radial
RGB	red giant branch
RINGS	RSS Imaging spectroscopy Nearby Galaxies Survey
RMS	root mean square
RSA	Republic of South Africa
RSS	Robert Stobie Spectrograph
RU	Rutgers University
SA	SALT Astronomer
SA	South Africa
SAAO	South African Astronomical Observatory
SAASTA	South African Agency for Science and Technology Advancement
SALT	Southern African Large Telescope
SALTICAM	SALT Imaging CAMera
SAMI	Sydney–AAO (Anglo-Australian Observatory) Multi-object Integral field spectrograph
SARAO	South African Radio Astronomy Observatory
SARS	South African Revenue Service
SCBP	SALT collateral benefits programme
SDSS	Sloan digital sky survey
SEDA	Small Enterprise Development Agency
SEFA	Small Enterprise Finance Agency
SIDECAR	system image, digitizing, enhancing, controlling, and retrieving
SITARE	Southampton–IUCAA training for astronomical research and education
SKA	Square Kilometre Array
SMBH	supermassive black hole
SMC	Small Magellanic Cloud
SMCN	nova candidate in SMC
SN	supernova
S/N	signal-to-noise
SNR	supernova remnant
SOAR	SOuthern Astrophysical Research telescope
SPIE	Society of Photo–optical Instrumentation Engineers
SPS	(mirror) segment positioning system
SpUpNIC	Spectrograph Upgrade – New Improved Cassegrain
SSME	small, medium, micro enterprises
SSS	supersoft X-ray source
SSWG	SALT Science Working Group
STC	scientific and technical committee
SZ	Sunyaev–Zel'dovich
TAC	time allocation committee
TESS	Transiting Exoplanet Survey Satellite
TMT	Thirty Meter Telescope
UCLan	University of Central Lancashire
UCT	University of Cape Town
UFS	University of Free State
UKSC	United Kingdom SALT Consortium
UNC	University of North Carolina – Chapel Hill
UNISA	University of South Africa
UV	ultraviolet
UW	University of Wisconsin–Madison
UWC	University of the Western Cape
VIRUS	Visible Integral-field Replicable Unit Spectrograph
VLA	Very Large Array
VLBI	very long baseline interferometry
VLT	Very Large Telescope
WASP	Wide Angle Search for Planets
WD	white dwarf
WISE	Wide-field Infrared Survey Explorer
WR	Wolf–Rayet
XMMU	XMM–Newton Observatory data, unique source
ZMQ	ZeroMQ

The SALT consortium is seeking an additional 10%-level partner (~$8.8M) 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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