Southern African Large Telescope



Annual Report 2013

The Board of the Southern African Large Telescope (SALT) is proud to present its Annual Performance Report for the period 1 January 2013 to 31 December 2013. This report offers an overview of the activities and performance of SALT, and highlights the impact of a selection of SALT research projects.

1. Introduction

The Southern African Large Telescope (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 across, comprising 91 individual 1m hexagonal mirrors. It is the non-identical twin of the Hobby-Eberly Telescope (HET) located at McDonald Observatory, Texas, USA. HET and SALT represent a completely new paradigm in the design of optical telescopes. The light gathered by its huge 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 and science funding agencies from Africa, India, Europe, New Zealand and North America. The South African National Research Foundation is the major shareholder with a $\sim$1/3 stake. Other large shareholders are Dartmouth College, the University of Wisconsin-Madison, Nicolaus Copernicus Astronomical Centre of the Polish Academy of Sciences and Rutgers University. Smaller shareholders include the American Museum of Natural History, the Indian Inter-University Centre for Astronomy and Astrophysics, the University of Canterbury (in New Zealand), the University of North Carolina, Göttingen University and the UK SALT Consortium, the latter representing the Universities of Central Lancashire, Keele, Nottingham and Southampton, the Open University and the Armagh Observatory. The size of the shareholding of each partner determines the access to the telescope which they enjoy. The HET Consortium, although not a shareholder, received ten per cent of the telescope time for the first 10 years of operation, in return for providing all the designs and plans of the HET as well as assistance during the construction of SALT.

SALT is located at the observing site of the South African Astronomical Observatory, near the small town of Sutherland, about 400 km north-east of Cape Town in the Karoo. 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.

2. Vision and Mission

SALT is a multi-partner enterprise, each of whom brings their own vision:

- The National Research Foundation (NRF) is the foundation in South Africa that supports the development of human resources skilled in science, engineering and technology disciplines through the provision of grants to tertiary training institutions and the

operation of national research facilities. The South African Astronomical Observatory (SAAO) is the national research facility in South Africa for optical/infrared astronomy operated by the NRF. The NRF is funded by the South African government through the Science Vote allocation from the Department of Science and Technology (DST). For the Government of the Republic of South Africa, SALT also presents a unique opportunity to overcome and redress the consequences of the policies of pre-1994 governments that excluded the majority of South Africans from science, engineering and technology education, training and careers.

- Rutgers, the State University of New Jersey (RU), USA is a public institution of higher education, teaching, and research, operating under the direction of its Board of Governors. RU believes that through a shareholding in the SALT Foundation, the participation in the activities associated with SALT will be of great value to the students, faculty, and other associates of the Department of Physics and Astronomy, to the University as a whole in its educational and research activities, and to the State of New Jersey.

- Georg-August-Universität Göttingen (GU) is a public institution of higher education, teaching, and research of the German Federal Country Lower Saxony (Land Niedersachsen). GU, represented by the University Observatory, Department II, is a Shareholder in the SALT Foundation. The Departmental faculty and students believe that access to SALT will greatly help them to carry out cutting edge research and teaching in Extragalactic Astronomy and that participation in the SALT collaboration under this Agreement will be a great asset to Göttingen University and to the Federal Country.

- The University of Wisconsin-Madison (UW) is a state institution of higher education within the University of Wisconsin System under control and supervision of the Board of Regents, a body corporate of the State of Wisconsin (USA). UW believes participation in SALT as a Shareholder will be of great value as a forefront laboratory for the Astronomy Department, and to the University as a whole in its research, educational, and outreach activities. They anticipate that the collateral benefits associated with the SALT project will be far-reaching within the University and State of Wisconsin.

- The University of Canterbury, New Zealand (UC), is a public institution of higher education, teaching and research within the New Zealand tertiary education sector. Access to SALT will provide scientific and technological opportunities for a new generation of New Zealand researchers, engineers and technicians. There will also be significant benefits for research-informed teaching.

- Nicolaus Copernicus Astronomical Center of the Polish Academy of Sciences (CAMK) is a public institution of research and represents the Polish community of astronomers who will participate in SALT. CAMK will be responsible for administering funds from the Polish budget provided by the State Committee for Scientific Research (KBN). CAMK, together with four Polish universities (Cracow, Poznan, Torun and Wroclaw) is also intending to create a foundation in Poland for sourcing funds from other resources for supporting the Polish participation in SALT. SALT will give the

Polish community of astronomers access to a large telescope facility in the southern hemisphere and enable faculty and students to carry out cutting-edge astronomical research.

- The United Kingdom SALT Consortium (UKSC), is a group of UK institutions that undertake research and teaching at higher education level. It comprises: The Armagh Observatory, The University of Central Lancashire, The University of Keele, The University of Nottingham, The Open University and The University of Southampton. The UKSC believes that participation in SALT will be of great value to students and staff of the institutions in their research programmes in astronomy and related sciences, and in the promotion of general understanding and appreciation of science, engineering and technology.

- The University of North Carolina-Chapel Hill (UNC-CH) is a state institution of higher education within the University of North Carolina system under the control and supervision of the Board of Governors, a corporate body of the State of North Carolina, USA. UNC-CH includes among its faculty engaged in research, teaching and service the Department of Physics and Astronomy. The Departmental faculty believe that its faculty and students, graduate and undergraduate, would benefit greatly by access to the Southern African Large Telescope.

- Dartmouth College is a private institution of higher learning, teaching, and research in the USA. Dartmouth faculty includes a Department of Physics and Astronomy engaged in teaching and research. Dartmouth believes that its faculty and its undergraduate and graduate students would benefit by having access to SALT.

- Inter-University Centre for Astronomy & Astrophysics (IUCAA) is an autonomous institute of the University Grands Commission (UGC) of India. 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, the IUCAA enables workers from Indian universities, teachers as well as students, to visit IUCAA for various durations for participating in research and executing developmental projects. The aim is to provide the visitors access to the best facilities needed for their research and development. For the past one decade IUCAA is supporting various observational programmes with its 2-m telescope at the IUCAA Girawali observatory. IUCAA believes that participation in SALT will help researchers from IUCAA and Indian universities carry out cutting edge Astronomical projects with a 10-m class telescope.

- The American Museum of Natural History's (AMNH) Astrophysics department is responsible for the scientific messages powerfully displayed in the exhibition halls of the Rose Center for Earth and Space in New York City. The Planetarium and Earth Science halls, as well as the museum itself host 5 Million visitors each year. The scientific staff in astrophysics carries out research based on ground and space-based telescope observation, computational modeling of star formation and extraterrestrial impacts, and direct imaging and characterization of exoplanets. AMNHs commitment

to outreach and lifelong learning are now extended to South Africa via SALT. As part of its outreach efforts in South Africa, the museum has donated copies of its state-of-the-art planetarium shows to South African planetaria; enrolled South African teachers in distance-learning courses; and hosted visiting groups of South African high schoolers and their teachers for week long visits to AMNH.

- The Hobby-Eberly Telescope Board (HETB) comprises a partnership including the University of Texas at Austin, Pennsylvania State University, Stanford University, Ludwig-Maximilians-Universität München, and Georg-August-Universität Göttingen. HETB was established for the design, construction, and operation of a similar 10-metre class telescope. The HETB will support SALT by licensing the use of plans, documentation, software and intellectual property owned by the HETB, in return for ten per cent of the telescope observing time during the first ten years of operations. HETB also plans to encourage scientific collaboration, exchanges of people and instruments, and student training opportunities between SALT shareholders and the HET participating institutions.

SALT will not only enable its partners to explore the mysteries of the Universe. It will play its part in developing a world in which all humankind is inspired and united by the pursuit of knowledge of the infinite variety and richness of the Universe.

The Mission of the SALT Foundation is simple. It is to design, construct, and operate a ten-metre class telescope, with instrumentation and related support buildings, and which is to be located at the Sutherland outstation of the South African Astronomical Observatory in South Africa, the purpose being to advance science and training through the promotion of astronomy and astrophysics in the southern hemisphere and to enhance collaboration between scientists and countries in these fields.

3. Chairperson's Overview

In writing this Overview to the SALT Annual Report 2013, I am struck by how many positive things have happened recently, and how rapidly the telescope's scientific capabilities are improving. Five semesters of routine science operations have now been completed since the Image Quality fix of 2011. In the two semesters of 2013, 212 proposals were awarded observing time. 17 peer-reviewed papers were published, (compared to 9 in 2012), with many more now in the pipeline.

The High Resolution Spectrograph arrived in Sutherland in September 2013, and was re-assembled in the spectrometer room. First light on sky was achieved on 28 September. Throughput and resolution are within specifications. Stability testing is underway, with good initial results.

A new autoguider for HRS is 8 times more sensitive than the RSS guider. The successful new design will be replicated for RSS.

The visible arm of the Robert Stobie Spectrograph was accepted from the University of Wisconsin. Replacement optics for its collimator are in fabrication, and will allow RSS to again meet its specifications.

The tracker upgrade project was initiated and is currently on time and budget; it is essential to provide the extra strength needed to bear the Near Infrared arm of RSS that will be delivered in 2016.

A Board of directors retreat identified the need to strengthen SALT's corporate risk management. We are deeply grateful to Dr. Thomas Auf der Heyde and Dr. Albert van Jaarsveld for leading the retreat before the November Board meeting.

Like all telescopes, we have endured some unpleasant (and occasionally scary) incidents. The SALTICAM optics suffered a water condensation event and apparent damage to its Anti-Reflective coatings. Fortunately, a careful cleaning fixed the problem, and there is no long-term damage to the throughput of the instrument.

During a particularly harsh winter storm the primary mirror suffered water condensation due to a prolonged power outage. The ongoing recoating of mirror segments is solving this problem, but the incident highlights the need for a robust standby generator with sufficient power to keep the air-conditioning units going during future Eskom power outages.

The overall prospects for SALT are increasingly bright, as more than a decade of hard work by its talented and dedicated staff is bringing rich scientific rewards.

4. Research Highlights

Although SALT entered full time science operations in late 2011, this is the first annual report produced for the wider astronomy and stakeholder communities which presents the science results from the telescope. The science results reported here represent the research outputs from many astronomers within the SALT community who responded to the request for reports on their SALT programs and particularly publications that have resulted from SALT observations. Of course some of these results have come from observations taken before 2013, but their completion and/or resulting publications have occurred during the year.

In total 17 refereed publications featuring SALT data were published during the calendar year 2013 and a further 3 conference proceeding papers appeared (see appendix). This has brought the totals to 29 and 16, respectively for refereed/non-refereed publication over the $\sim$2 years of science operations to date (i.e. Nov 2011 Dec 2013). The publication rate is increasing steadily, reflecting the maturity of the telescope, instruments and operations as SALT enters a steady-state.

Some science highlights for the year included the discovery of the third closest stellar system, a brown dwarf binary discovered from the WISE infrared satellite (see report by Kniazev et al.). Target of opportunity observations have also featured in recent SALT publications, particularly monitoring of supernovae (see report by Milisavljevic et al.). Such results demonstrate SALTs ability to undertake observations at short notice and with a cadence suited to the science requirements, an inherent advantage of flexible real-time scheduling with a 100% queue-scheduled service observing mode.

The current status of SALT compares favorably with other large telescope facilities at a similar phase of their development. A recent paper (Crawford et al. 2014) compared various metrics and publication outputs for 8-10m telescopes, including SALT. For the period of 2 years following the start of science operations (in 2011 for SALT), the number of total

refereed publications (now 50) is on a par with other large telescopes. Considering that the operations budget for SALT is typically half of these other facilities, if the publication rate is normalized by the annual operations cost, then SALT is performing well ahead (by ∼2) of comparable international facilities.

A selection of some of the results obtained with SALT are summarized below.

Stellar and Galactic Astronomy

SALT spectroscopy of a brown dwarf binary at 2 pc from the Sun:

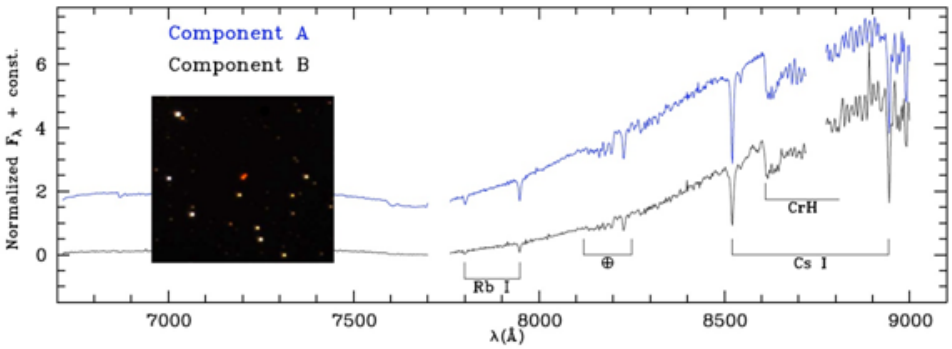


Figure 1: RSS/SALT spectra of the two components of WISE J104915.57−531906.1, typed as L8 and T1.5 brown dwarfs. The inset shows an RSS image highlighting the extremely red colour of the target - the 8175Å, 7260Å, and 5060Å interference filters were used for the three-colour image.

On March 11, 2013, Penn State issued a press release of the detection of the closest star system found in a century, based on proper motions from WISE (Wide-field Infrared Survey Explorer) data. Gemini imaging had showed two objects at the location of WISE J104915.57−531906.1 and a spectrum confirmed one of them to be a L8 type brown dwarf. The following night, March 12, SALT took spectroscopy under Directors Discretionary Time (DDT) to measure the radial velocities and spectral typing of both components (see Fig. 1). The PG1800 and PG900 grating long-slit observations with RSS clearly resolved two objects just 1.5 arcsec away from each other. Comparing to templates the A-component was confirmed as an L8±1 type while the B-component was determined to be a T1.5±2 type dwarf. Their radial velocities of 23.1 and 19.5 km s^{-1}, respectively, were calculated from Rb I and Cs I lines with a 1 km s^{-1} accuracy. Together with mass estimates, based on temperatures and IRSF (Infra-red Survey Facility) NIR magnitudes obtained at the same time, and assuming a circular orbit, the radial velocity differences indeed imply a bound binary with a likely orbital period of approximately 20 yrs. The motion of the binary system does not place it in any known nearby young moving group or association. Being such a close-by neighbor WISE J104915.57−531906.1 (also known as Luhman 16) has since been a subject of numerous other studies at other telescopes. These SALT observations, in addition to being the first to characterise its velocities and motions and typing the secondary, also demonstrated the rapid response possible with the DDT-mode of observations and the

successful techniques available to reduce extremely red and strongly fringed RSS spectra [as reported by *A. Kniazev (SAAO/SALT), P. Vaisanen (SAAO/SALT), V. Ivanov (ESO)*].

SXP5.05: An eclipsing Be X-ray binary in the Small Magellanic Cloud:

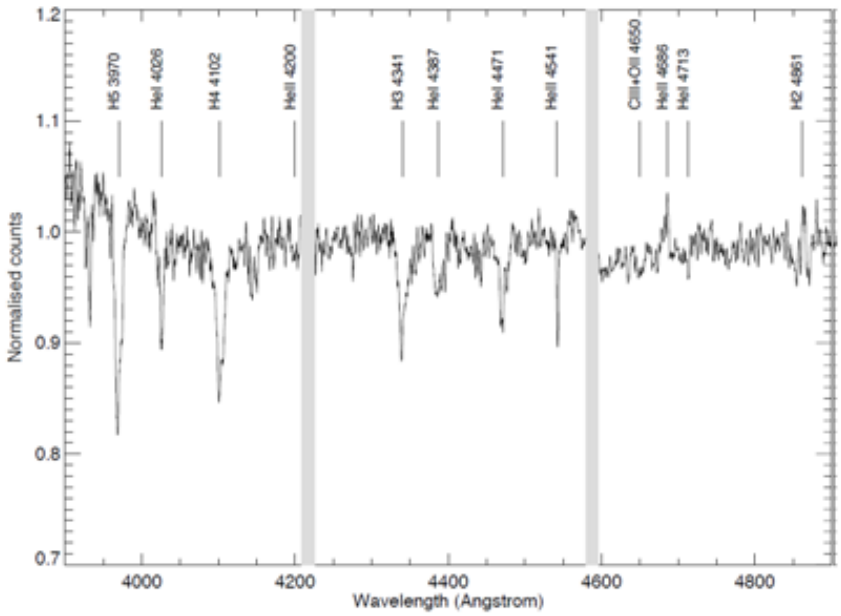


Figure 2: SALT/RSS spectrum of SXP5.05, taken with grating PG2300 and a 1000 s exposure time.

On 25 October 2013, the INTEGRAL gamma ray satellite discovered a bright flare from an unknown X-ray source in the Small Magellanic Cloud (SMC). Supporting XMM-Newton observations constrained the position of the high energy source and a rapid spectroscopic follow up was performed by SALT through a target of opportunity (ToO) proposal. The SALT observations allowed determination of the spectral type, as an early type star with Balmer emission, with SALT monitoring of the Hα line throughout 2 months of the 3 month long outburst. The spectrum also shows He II 4686 in emission, which is unusually for the spectral type and is probably a signature of a hot accretion disk (see Fig 2). Long term X-ray and optical monitoring observations have been crucial to the discovery the first Be X-ray binary that shows X-ray eclipses, and have provided a wealth of data for constraining the orbit and the circumstellar disk + neutron star interactions. [as reported by *V. McBride (SAAO/UCT)*]

SALT Observations of SXP1062:
SXP1062 is a Be/X-ray binary associated with a Supernovae remnant in the Small Magellanic Cloud. Estimates of its age from the size of the supernovae remnant place this object around $1 - 2.5 \times 10^4$ years old. This is unusual since the pulsar has not had sufficient time to spin down to its current spin period of 1062 seconds through the traditional processes. It is speculated that the neutron star was either born as a magnetar or with an unusually slow birth spin period. Towards the end of 2012, Schruch and collaborators performed a target of opportunity observation of SXP1062 whilst it was undergoing a Type-I X-ray outbursts close to its maximum brightness. Red and blue spectra were taken to allow measurements

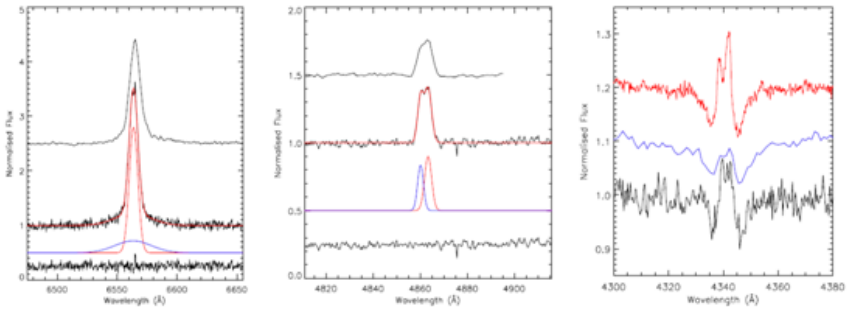


Figure 3: Left: Hα as seen with SALT (normalised) and modelled with two Gaussian components and a smooth continuum. The lowest line gives the residuals. The 2dF spectrum is shown on the top for comparison. Middle: same as before, but for Hβ. Right: Hγ as seen with VLT/FLAMES (top), 2dF (middle) and SALT (bottom).

of the equivalent widths of the Hβ and Hγ emission lines (shown in Fig. 3) originating from the circumstellar disk of material surrounding the B-type counterpart star. These spectra were compared to previous data taken by the Two Degree Field (2dF) spectrograph. There has been a small level of change in the emission lines over the course of 13 years, with the most pronounced variations occurring in the H γ line. Estimates of the orbital period suggested that the next outburst would be during June/July 2014. A joint Swift, Chandra and SALT campaign to study the outburst decay at 4 epochs was scheduled. The outburst began at the start of June and data was taken with all telescopes. These data are currently being evaluated [As report by *M. Schurch (UCT)*].

SALT Observations of Circinus X-1:

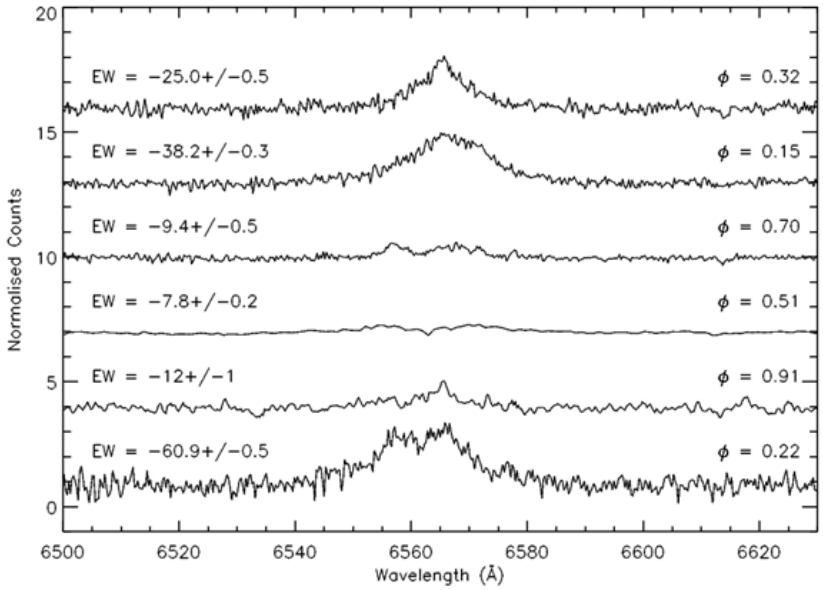


Figure 4: Variability of Hα emission line towards Circinus X-1 as observed with SALT/RSS.

Circinus X-1 has always been an object of great interest to the astronomical community and in particular those studying X-ray binaries. In 2007 it was reported that the radio flaring was once again reaching $\sim Jy$ levels for the first time in 20 yr (Nicolson, 2007, ATel 985). This was then followed by a return to the strong X-ray flaring through observations with the MAXI (Monitor of All-sky X-ray Image) all sky monitor. This renewed activity made Circinus X-1 a particularly useful target for combined optical and radio observations using SALT and the SKA precursor, KAT-7. Circinus X-1 was observed 6 times during 2012 using the SALT RSS. Two observations, during April 2012, were made at its highest resolution setting, while two during August coinciding with radio observations, and two during August 2012, were made in a lower resolution mode. Due to the extremely high extinction towards the system we focused these observations on the Hα emission line and the Paschen lines. Unfortunately weather and operational issues prevented further observations that were planned to be simultaneous with the radio.

As can be seen in the Fig 4, the H α emission line is extremely variable (observations run from April 2012 bottom to August 2012 top). A double peaked structure can be seen to almost totally disappear and then reform as a single peaked profile. This behaviour has been seen before and is likely linked to the large outbursts that take place periodically at periastron. The emission line is successfully modelled using three components where one component remains at a fixed position whilst the remaining two vary in velocity space. It suspected that these varying components could be arising in an accretion disk around the neutron star or in a warped decretion disk that has an X-ray heated hot spot. Further observations made at regularly spaced orbital phases during a single orbit would be necessary to fully explore this highly variable system [as report by *M. Schurch (UCT)*].

First stars in the flared disk of the Milky Way:

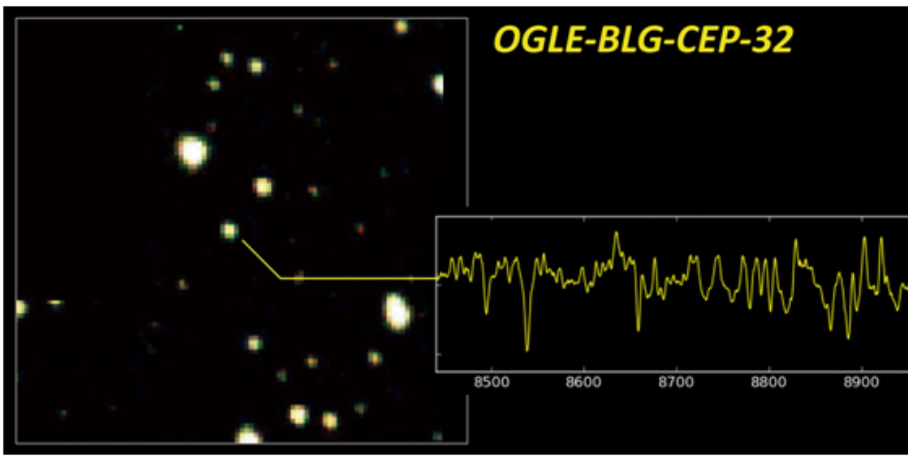


Figure 5: Spectrum of one of the Cepheids, OGLE-BLG-CEP-32, obtained with the Robert Stobie Spectrograph (RSS), is shown, together with an IR image taken on the SAAO 1.4-m IRSF.

Flaring and warping of the disk of the Milky Way has been inferred from observations of atomic hydrogen but stars associated with flaring have not hitherto been reported. In the area beyond the Galactic centre the stars are largely hidden from view by dust, and the kinematic distances of the gas cannot be estimated. Thirty-two possible Cepheid stars (young pulsating variable stars) in the direction of the Galactic bulge were recently iden-

tified in the OGLE (Optical gravitational lensing experiment) Bulge survey. With their well-calibrated period-luminosity relationships, Cepheid stars are useful distance indicators. When observations of these stars are made in two colours, so that their distance and reddening can be determined simultaneously, the problems of dust obscuration are minimized. Feast, Menzies, Matsunaga and Whitelock (Nature 509, 342, 2014) reported that five of the candidates are classical Cepheid stars. These five stars are distributed from approximately one to two kiloparsecs above and below the plane of the Galaxy, at radial distances of about 13 to 22 kiloparsecs from the centre. Radial velocities from SALT spectra (see an example given in Fig. 5) were crucial in showing that these stars belong to the Milky Way rather than being a young component of a stream from the Sgr Dwarf galaxy. The presence of these relatively young (less than 130 million years old) stars so far from the Galactic plane is puzzling, unless they are in the flared outer disk. If so, they may be associated with the outer molecular arm [as report by: *M. Feast (UCT)*].

A large haul of new Galactic symbiotic stars:

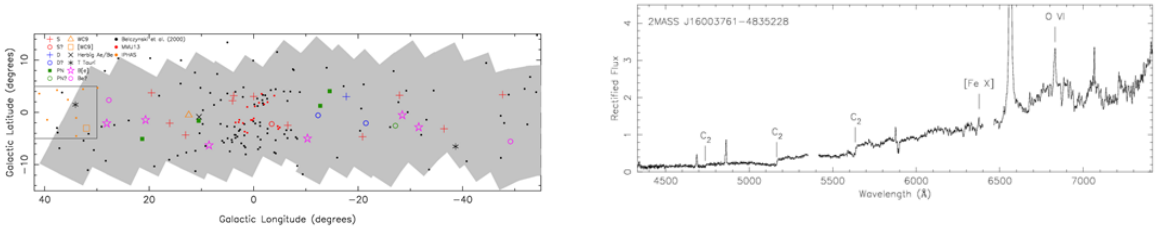


Figure 6: *Left:* Galactic distribution of the new symbiotic stars discovered with SALT RSS (red and blue crosses). *Right:* SALT/RSS spectrum of 2MASS J16003761-4835228 reveals the rare carbon-rich giant with prominent C2 bands and the very high ionization line [Fe X] 6375 Å, suggesting it may be a supersoft X-ray source.

Symbiotic stars are interacting binaries that are strong candidates for type Ia supernovae (SN Ia) progenitors, however the Galactic population is not well characterised. Miszalski & Mikoajewska used SALT/RSS to discover 12 new symbiotic stars in the Southern Galactic Plane (left panel in Fig. 6) in their ongoing SALT program to observe several H-α emission line candidates selected from the AAO/UKST SuperCOSMOS Hα Survey and 2MASS. It aims to build an improved census of Galactic symbiotic stars, of which less than 300 are currently known. A particularly exciting result is that one of the new discoveries exhibits [Fe X] 6375Å emission, making it a supersoft X-ray source candidate (right panel in Fig.6). Supersoft sources are intimately linked to SN Ia progenitors since they are steadily burning hydrogen on the white dwarf. Several more such discoveries are anticipated as the survey progresses [as report by *B. Miszalski (SALT/SAAO)*].

LIN9: A new Small Magellanic Cloud symbiotic star:
Miszalski, Mikoajewska & Udalski used SALT/RSS to discover a new symbiotic star, LIN 9, in the periphery of the Small Magellanic Cloud (SMC, Fig. 7). This brings the total number of known symbiotic stars in the SMC to eight, on par with the known LMC population. It is the first demonstrated extragalactic symbiotic star to show so-called Z And outbursts, visible in the OGLE lightcurves of the object (Fig. 7). The outbursts are thought to be due to instable disc-accretion onto a hydrogen-shell burning white dwarf, but the process is far from well understood. At the known distance of the SMC, LIN 9 may in the future play a

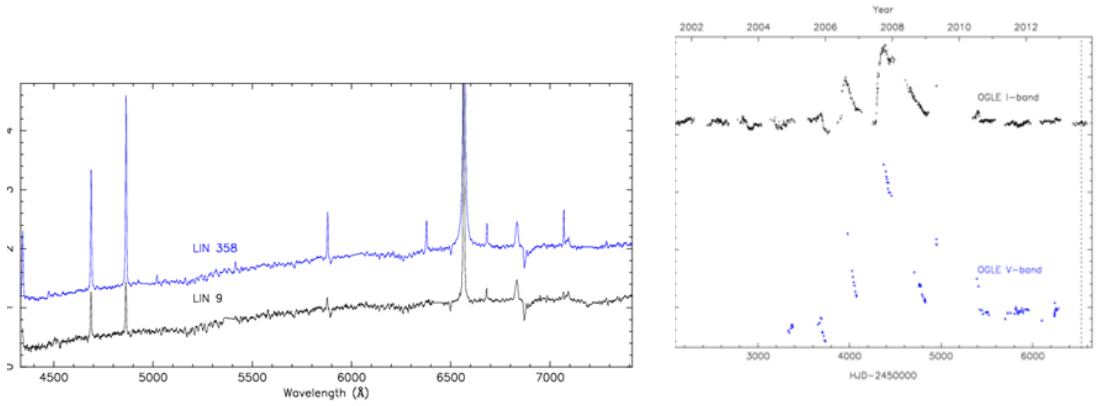


Figure 7: *Left:* SALT/RSS spectra of SMC symbiotic stars LIN 9 (new) and LIN 358 (a known supersoft X-ray source). *Right:* OGLE V-band and I-band lightcurves of LIN 9, used to select the object for follow-up spectroscopy with SALT/RSS.

pivotal role in building a realistic physical model of the phenomenon. The discovery of LIN 9 suggests other undiscovered Magellanic symbiotic stars could also be found with the help of lightcurves from large monitoring surveys [As report by *B. Miszalski (SALT/SAAO)*].

Optical spectroscopy of stars with mid-infrared shells:

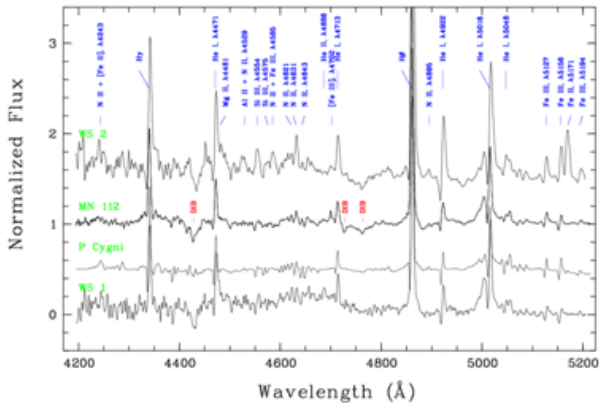


Figure 8: Comparison of normalised blue spectra of newly identified cLBVs WS1 and WS2 with those of the prototype LBV P Cygni and cLBV MN112.

Massive stars are sources of strong stellar wind whose interaction with the ambient medium during the Wolf-Rayet (WR) and Luminous Blue Variable (LBV) phases results in formation of circular, bipolar or triple-ring circumstellar nebulae. Detection of nebulae reminiscent of those associated with WR and LBV stars using archival data of the modern infrared (IR) telescopes (Spitzer, WISE) serves as an indication that their central stars are evolved massive ones, while spectroscopic follow-ups of these stars allows one to verify their nature. SALT spectroscopy of several dozens of stars with mid-IR shells led to the discovery of numerous candidate LBV (cLBV) (see Fig. 8 for spectra of two newly identified cLBVs WS1 and WS2) and related evolved massive stars (Kniazev et al., in preparation). The

SALT data were also used to identify the binary status of a new WR star in the Large Magellanic Cloud (revealed through the detection of a mid-IR shell with Spitzer) and to discover an He III region centred on this star (only few such high excitation nebulae are known in the Local Group). A by-product of the SALT spectroscopic observations of stars with mid-IR shells is the discovery of a rare WN-type central star of a planetary nebula [As report by *A. Kniazev (SALT/SAAO)*].

A barium central star of the planetary nebula Hen2-39:

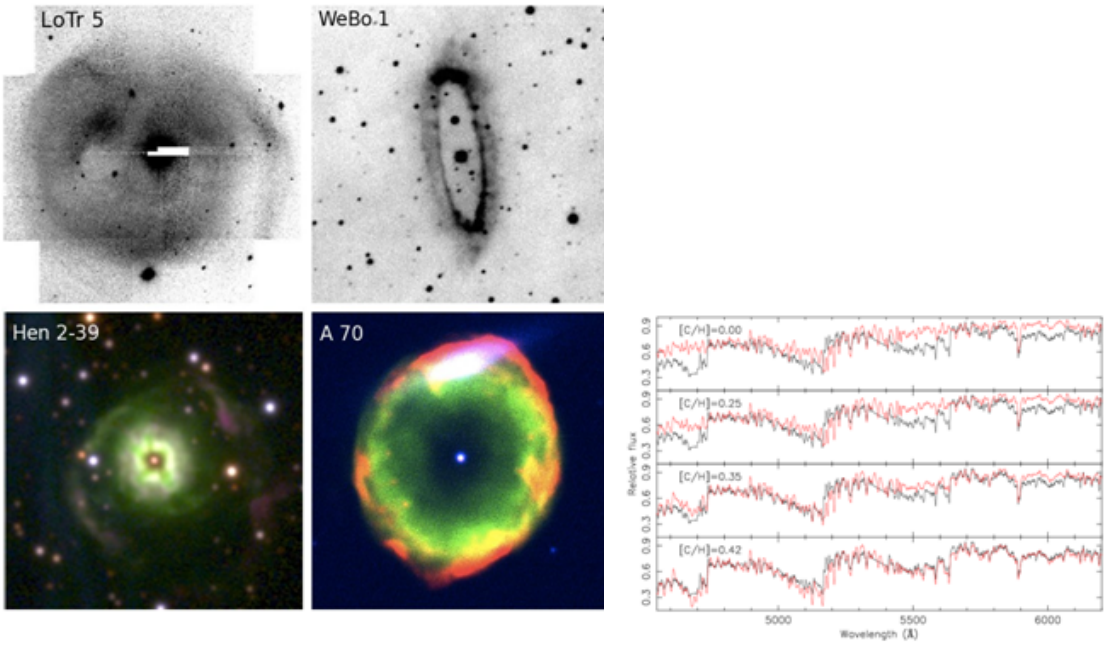


Figure 9: *Left:* A montage of the currently known barium central stars of planetary nebulae (LoTr 5, Graham et al. 2004, MNRAS, 347, 1370), WeBo 1 (Bond et al. 2003, AJ, 125, 260), A 70 (Miszalski et al. 2012, MNRAS, 419, 39) and the recent SALT RSS discovery of Hen2-39 (Miszalski et al. 2013, MNRAS, 436, 3068). Apparent ring morphologies appear to be common, but the intrinsic shape can only be determined with detailed spatio-kinematic modelling (see Tyndall et al. 2013, MNRAS, 436, 2082). *Right:* SALT RSS spectra of Hen2-39 confirm the barium star nature of Hen2-39 with enhancements of [C/H]=0.42 dex and [Ba/Fe]=1.50 dex.

Miszalski and his collaborators have used SALT/RSS to discover a rare barium central star of a planetary nebula inside Hen2-39. This is the fourth known member of a rare group of central stars (see left panel in Fig. 9). SALT/RSS spectra confirm the carbon-rich and barium-rich nature of the red giant. It is too cool to ionize the surrounding nebula. The nebula is actually been ionized by an invisible white dwarf companion in an orbit of a few hundred days or longer. Earlier in its life, just before the white dwarf ejected the planetary nebula, its strong wind was loaded with carbon and s-process elements, and this was accreted by the companion, which we now see polluted with this chemical signature (see right panel in Fig. 9). The whole ensemble found in these barium stars with planetary nebulae make them particularly powerful laboratories for studying chemical nucleosynthesis and mass transfer in evolved stars [as report by *B. Miszalski (SALT/SAAO)*].

Discovery of a bow-shock-producing red supergiant star:

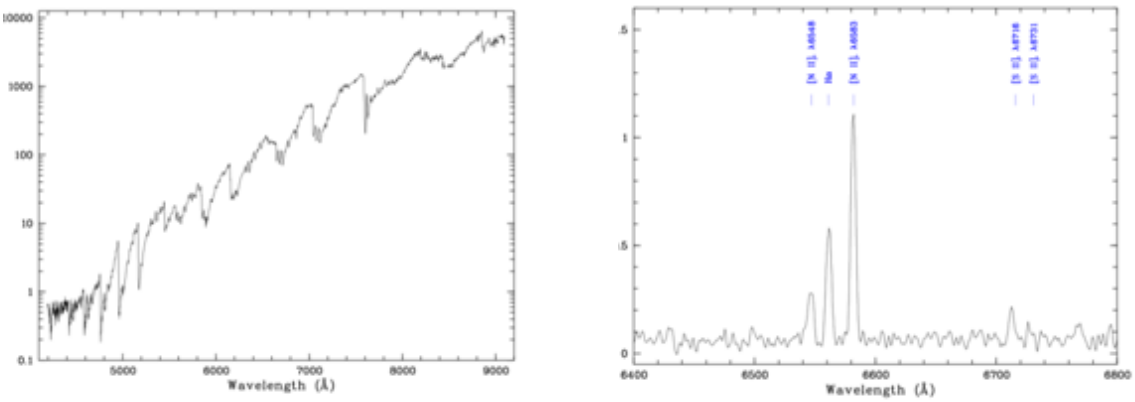


Figure 10: *Left:* SALT/RSS spectrum of the central star IRC10414. *Right:* Spectrum of the arc-like nebula associated with IRC10414 in the region of the Hα line.

Most runaway OB stars go through the red supergiant (RSG) phase during their lifetimes. Nonetheless, although many dozens of massive runaways were found to be associated with bow shocks, only two RSG bow-shock-producing stars, Betelgeuse and μ Cep, are known to date. Using the SuperCOSMOS H-α Survey, an arc-like nebula around the late M-type star IRC 10414 was discovered. Spectroscopic follow-up of IRC10414 with the SALT (see left panel of Fig. 10) showed that it is a M7 supergiant, which supports previous claims on the RSG nature of this star based on observations of its maser emission.

Using the recent proper motion measurement for IRC10414, it was estimated that the space velocity of this star to be 70$\pm$20 kms^{-1}, which implies that IRC10414 is a classical runaway. This finding, along with the arc-like shape of the nebula, suggests that the nebula is a bow shock. The bow shock interpretation was reinforced by the SALT spectrum of the nebula (see the right panel in Fig. 10), which yields the [S II] 6716, 6731/Hα ratio typical of shock-excited nebulae. From intensities of the [N II] and [S II] lines detected in the spectrum of the bow shock, it is found that the line-emitting material is enriched in nitrogen. This is considered as an indication that the bow shock emission at least partially originates in the shocked stellar wind, which in RSGs is overabundant in nitrogen because of the dredge up of the nuclear processed gas. Detection of the bow shock around IRC10414 makes this star the third case of bow shock producing RSGs and the first one with a bow shock visible in the optical range [As reported by *A. Kniazev (SALT/SAAO)*].

SALT spectroscopy of the unique helium nova V445 Puppis:
V445 Puppis is the only known helium nova in the Galaxy. On 11 March and 29 April 2013, 12.5 years after the nova outburst of V445 Puppis and 6 years after the last optical spectra had been obtained using Magellan/IMACS, a long-slit spectrum of V445 Puppis along the major axis of the nova ejecta (see Fig. 11) was obtained using SALT/RSS. The observations were part of a quasi-simultaneous campaign of optical imaging and spectroscopy, where the optical imaging of the nova remnant was obtained (for the first time) using the Hubble Space Telescope using a number of narrow-band filters centred on strong optical emission lines. The HST imaging was performed on 16 April 2013. The 2013 SALT/RSS spectrum, contemporaneous with the HST imaging, shows the emergence of a significant continuum

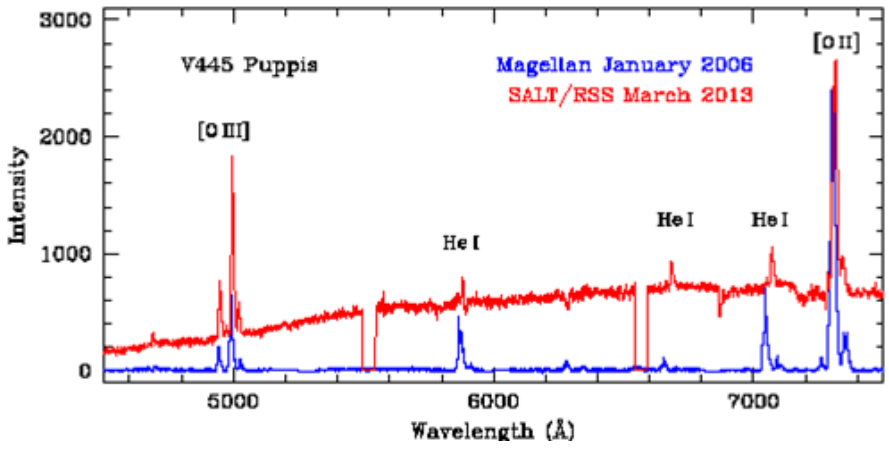


Figure 11: Observed SALT spectrum of V445 Puppis.

component in the emission of the nova remnant. A comparison of the SALT spectrum with the 2006 optical spectrum of V445 Puppis obtained with Magellan/IMACS. The bipolar velocity structure in the emission lines of the nova shell is still present in the [O II] and [O III] lines. This velocity structure was interpreted as a bipolar outflow in the spatio-kinematic model of Woudt et al. (2009) from which a distance of 8.2 kpc was derived. In contrast, the structure of the helium recombination emission lines have changed into a single-peaked line centred on the systemic velocity. A second epoch of HST imaging is scheduled for Cycle 22 (early 2015) and the spectroscopic evolution of V445 Puppis is being monitored continuously. The two-year baseline of optical imaging (HST) and optical spectroscopy (SALT) of V445 Puppis will allow one to test and refine the spatio-kinematic model of the shell ejecta, and thus derive a more accurate distance to the system. [As reported by *P. Woudt (UCT)*].

New β Cephei variable in the Southern open cluster NGC 6200: ALS 3728: The evidence of a new β Cephei type variable located in the Southern open cluster NGC 6200: ALS 3728 has been reported by Ulusoy and collaborators. Spectroscopic and photometric observations of NGC 6200 stars were carried out with SALT/RSS. It was found that ALS 3728 has a frequency of about 4.95 d^{-1} with highest amplitude. The star also shows a remarkable stillstand phase just before its light maxima which is a typical characteristic occurring among these type of stars. Furthermore, a mode identification is applied for the dominant frequency calculated from the Fourier analysis. [As reported by, *Ulusoy and collaborators (Poland)*].

An asteroseismic study of the Southern Cephei star ALS 3721 The results of a new investigation aimed to identify the pulsational characteristics of the Southern β Cephei star ALS 3721 has been presented by Ulusov and collaborators. Spectroscopic and multicolour photometric data were acquired with SALT/RSS Frequency analysis showed that the oscillations of ALS 3721 could be attributed to the two main frequencies with higher significance. Stellar parameters and projected rotational velocity obtained by the spectra were also used to perform photometric mode identification. In order to determine spherical harmonic degrees (l), a principal method was followed by comparing the observed light amplitude ratios in different passbands with those computed from

non-adiabatic pulsation models. In general case, therefore, the spherical harmonic degrees corresponding of the frequencies were found in the expected β Cephei range. [As reported by, *Ulusoy and collaborators (Poland)*].

Extra-galactic astronomy

Star Formation histories in S0 galaxies: Bulge Growth in NGC 2328:

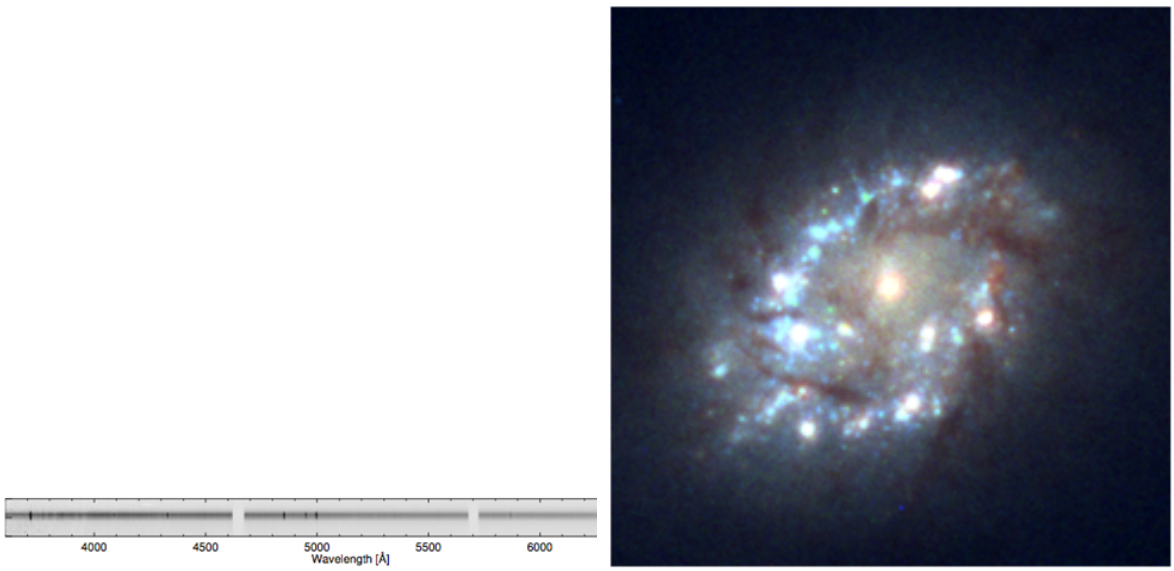


Figure 12: *Right:* The full 2D spectrum of NGC 2328 at rest wavelength from SALT/RSS. *Left:* The central kiloparsec of NGC 2328 as an HST 3-colour image where blue is F555W, green F814W and red F160W. A tight ring or spiral pattern is evident, lit up by star clusters, the youngest of which stand out in blue. Darker dust lanes are also present.

NGC 2328 is catalogued as an isolated E/S0 galaxy at a luminosity distance of $d_L \sim$18 Mpc (z = 0.0039). It is a low luminosity object and with M_B of -18.5 mag. It is right at the upper edge of what could be considered as dwarf galaxies. Long-slit spectroscopy with the RSS spectrograph at SALT was obtained for NGC2328 using PG0900 grating with a 0.6 slit were used to get a $R \sim 2000$ resolution and the = 3640 to 6765 Å range. 2D bulge/disk decomposition of F160W image obtained using WFC3 on board HST show no bulge. HST data in F555W, F814W, F658N and F160W bands reveal star formation in a 300 pc ring or nuclear spiral in form of Super Star Clusters (SSCs). Modeling of these SSCs populations shows the 5-100 Myr age. This means SSCs are formed only at this latest episode of star formation. SALT 2D spectra show an intense very young starburst of 5-50 Myr with old evolved population. It has been speculated that the star formation was triggered by lower metallicity minor merger. Super Star Clusters (SSCs) disrupt to centre and eventually contributing to growth of bulge in NGC2328 [as Reported by *S. Barway (PI, SAAO), P. Vaisanen (SALT/SAAO), A. Kniazev (SALT/SAAO), K. Vaghmare (IUCAA), Y. Wadadekar (NCRA, India) and A. Kembhavi (IUCAA, India)*].

Emission-Line Spectroscopy of Galaxies in the RESOLVE Survey:

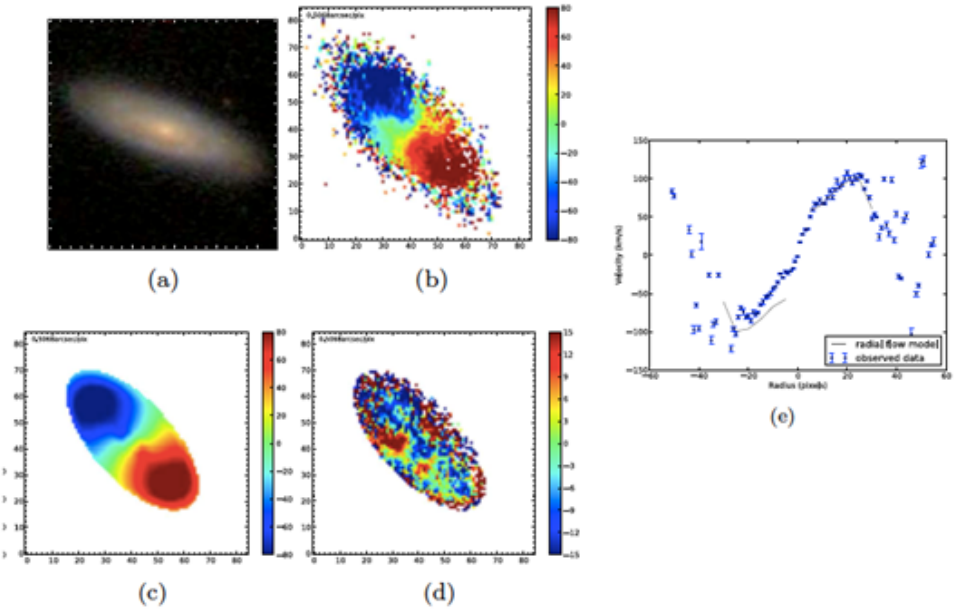


Figure 13: A example of RSS Fabry-Perot data taken as part of the RESOLVE survey.

The RESOLVE Survey (REsolved Spectroscopy Of a Local VolumE; Kannappan & Wei 2008) is an ambitious 5-year program to create a volume-limited census of stellar, gas, and dynamical mass, as well as star formation and merging, for all galaxies with baryonic mass above $\sim 10^9$ $M_\odot$ in $> 50,000$ cubic Mpc of the nearby universe (science projects led by scientists from UNC, Rutgers, and South Africa). The survey spans multiple interconnected filaments, walls, voids, and clusters in two equatorial strips, chosen to maximize overlap with a growing multi-wavelength treasury, including SDSS, GALEX MIS, UKIDSS, AKARI, WISE, the massive blind ALFALFA 21cm survey, and future ALMA observations of molecular gas.

The core data product of RESOLVE is 3D optical spectroscopy from the SOAR 4m and SALT 11m telescopes, providing kinematics, stellar population diagnostics, and gas metallicity and star formation information. RESOLVE's complete inventory consists of ∼1600 galaxies, of which ∼20% require the collecting area of SALT for high-resolution kinematics. Building on this treasury, the unique new data product of RESOLVE is high spatial and spectral resolution optical spectroscopy from the SOAR 4m and SALT 11m telescopes, targeting all ∼1600 galaxies above the mass limit in the survey volume. Combining these data with a very complete redshift survey, built by adding to the SDSS, will enable the first-ever high dynamic-range view of the distribution of total, kinematically estimated mass on scales from dwarf galaxies to clusters. Fig 13 shows an extract from the completed M.Sc thesis by E. Naluminsa (SAAO/UCT), which entailed detailed analysis of RSS Fabry-Perot data taken as part of the RESOLVE survey. The Diskfit analysis and interpretation can be used to probe gas inflows and outflows in local galaxies. [As reported by *I. Loubser (North West University)*].

SALT Observations of Gravitationally Lensed Herschel Systems:

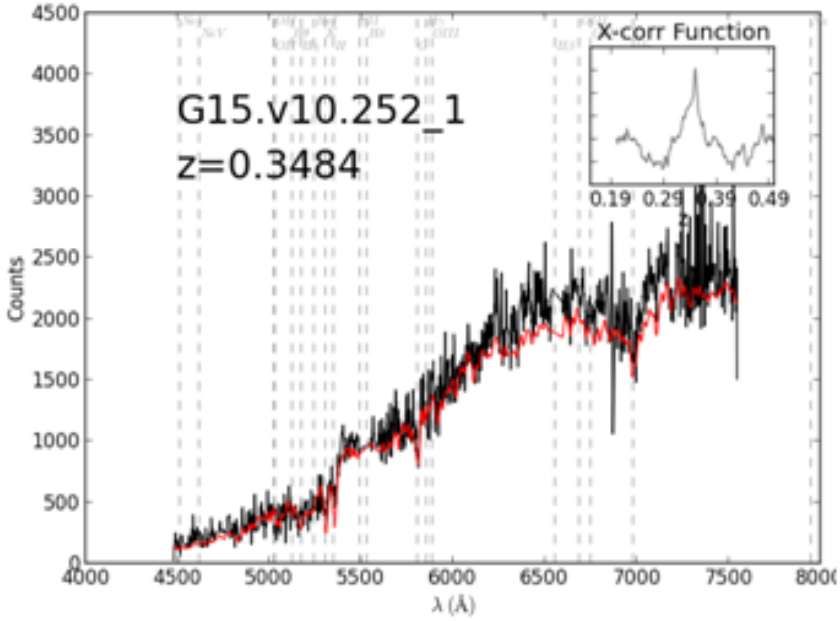


Figure 14: Spectra of a Lens galaxy taken with RSS/SALT.

A systematic optical spectroscopic follow-up campaign of newly discovered Herschel-ATLAS (H-ATLAS) lens candidates is been carried out using the Robert Stobie Spectrograph (RSS) on SALT in long-slit mode. The program is planned for a few semesters. A brightness limit of V∼20.5 is imposed and slits are aligned to a nearby bright object, a strategy that has improved the results, allowing secure redshift determinations and improved observing time efficiency. By combining such measurements with the on-going studies of the H-ATLAS galaxies using telescopes around the world, including high-resolution mapping with ALMA, SMA, VLA, PdBI, and CARMA and CO redshift searches of the lensed galaxies with the GBT and APEX, source-plane properties of a large sample of sub-millimeter galaxies (SMGs) will be derived and the evolution of the dark matter distribution in an equally large sample of lensing galaxies will be traced. Where possible, the slit positions of the lens targets are chosen to also produce auxiliary spectra of other sources that can be obtained in the same set-up as the main targets and are of scientific interest to the SALT and H-ATLAS community.

An example of the lens spectra and redshifts determined from the study is presented in Fig 14. The SALT spectra are confirming the foreground distance of the candidate optical lensing galaxies,that were first estimated from photometry, to be between redshift z∼0.2 and one and constraining their uncertainties by $dz \sim \pm 0.002$. Thus the SALT data will provide a better handle on the lensing geometry, mass and magnification, with implications on constraining the physical properties of the lensed and lensing galaxies. [As report by *L. Leeuw (University of South Africa), Steve Crawford (SAAO/SALT), in collaboration with the H-ATLAS Lensing team (www.h-atlas.org), that includes SALT partners from the UK, Rutgers, and New Zealand*].

Charting Cosmic Flows into the Zone of Avoidance: An inventory of the mass

distribution in the local universe has for decades remained incomplete due to the obscuration of the Milky Way. Concerted efforts have lead to galaxy surveys in the Vela and Hydra/Antlia regions and revealed a highly significant mass structure at a mean redshift of 18,000 km/s (roughly 100 20 Mpc). Given recent residual bulk flow results (of the order of 270 km s^{-1} at radii of >16000 km s^{-1}; SMAC, 6dF) these data provide a tantalizing link to structures beyond 100 Mpc that appear to be influencing the motion in the local universe. This previously unrecognized galaxy over-density in Vela may be key to resolving the recent highly contentious findings regarding the apex and convergence radius of the CMB dipole. The relatively low foreground extinction in Vela provides a window into the Zone of Avoidance that can be exploited by using the sensitivity and efficiency of SALT to (a) establish the extent of this structure and (b) identify the central clusters that theory predicts reside at the bottom of such deep potential wells. RSS MOS is optimally suited for this task - as proven by the observations. A total of 12 RSS-MOS fields have been observed

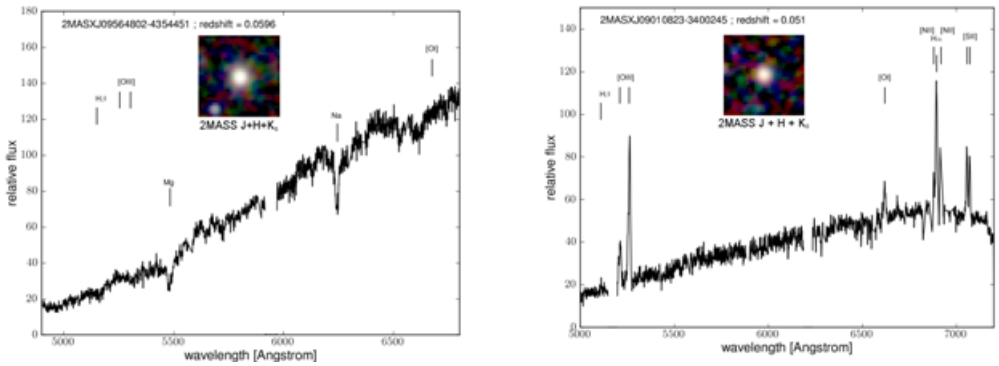


Figure 15: Typical RSS spectra of galaxies in the Vela over-dense region

between 2012 and 2013, of which 120 spectra were extracted and 80 have good-quality redshifts. A couple of examples are given in Fig. 16, the first an example (left panel) of an absorption-line dominated early type galaxy and the second (right panel) a late spiral galaxy with strong emission lines. These were obtained with a total exposure time of 800 s using the SALT RSS-MOS instrument. Both are located in the massive Vela over-density. [As report by *T. Jarrett (UCT), R. Kraan-Korteweg (UCT), M. Cluver (UCT), M.Bilicki (UCT)*].

SALT & The Dark Energy Survey:
Observations of high-redshift ($z \sim 1$) Type Ia supernovae (SNe Ia) provided the first direct evidence that the expansion rate of the Universe is accelerating. This revolutionary discovery has created a mystery central to our understanding of fundamental physics: what is the nature of the enigmatic dark energy responsible for cosmic acceleration? The Dark Energy Survey (DES) is a 5 year experiment, using the Blanco telescope at Cerro Tololo in Chile, which aims to put the most precise constraints on the composition of the Universe. Over this time, it is expected to discover ∼4000 SNe Ia, and use these, in combination with other cosmic probes, constrain the expansion history of the Universe over cosmic time (through its equation-of-state parameter w) to 1%. However, DES only provides photometric observations, and without spectroscopic follow-up, its final cosmological estimates will be potentially biased and limited by systematic uncertainties. Spectroscopic measurements provide a unique insight into the nature and dispersion of SNe Ia, providing an avenue to

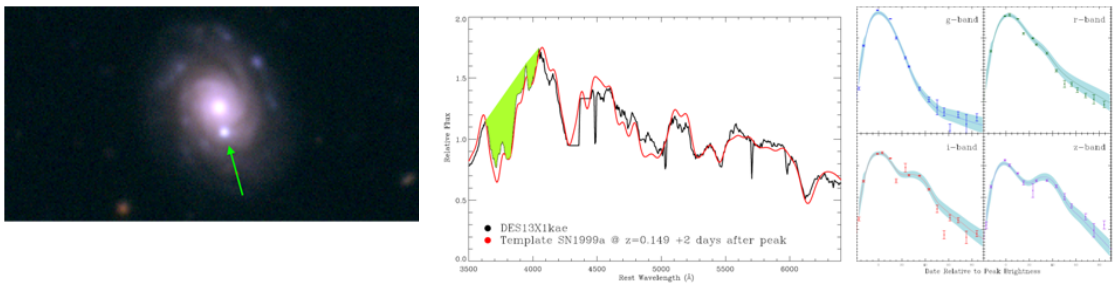


Figure 16: *left:* A zoomed in image of DES13C1feu, the first spectroscopically confirmed SNe by DES. This object was spectroscopically confirmed by DES to be a type Ic SNe at z=0.06. *Middle:* spectrum obtained by SALT of DES13X1kae. This candidate has been conclusively typed as a SN Ia just after maximum brightness. Overplotted in red is a template SN Ia spectrum at z = 0.149. *Right:* Multicolour (g,r,i,z) light-curve of DES13X1kae, a z = 0.149 SN Ia discovered during the first full season of DES observations. Overplotted in blue is the best-fitting light-curve template as determined by the pSNID classifier.

study the potential evolution of SNe Ia population with redshift and produce cosmological constraints independent of photometric standardisation methods. With its large primary mirror and location in the southern hemisphere, SALT is ideally suited to address these questions. In semesters 20131 and 20132, researchers at UWC, SAAO and AIMS used RSS on SALT to spectroscopically follow-up the first candidate SNe from DES. To date, SALT has spectroscopically confirmed 6 SNe (4 SNe Ia and 2 core-collapse SNe), highlighting the capability of SALT in carrying out cutting edge research. Over forthcoming semesters, the team will, for the first time, construct a homogeneously observed catalogue of SNe Ia spectra outside of the local Universe, ideally suited for probing SNe Ia evolution and diversity. This research has been prominently featured in several South African media outlets and over the next 2 semesters we anticipate producing a statistically significant dataset, ideal for studying the properties of these astrophysical phenomena [As Reported by *M. Smith (UWC), E. Kasai (UWC), B. Bassett (AIMS/SAAO), S. Crawford (SAAO), R. Maartens (UWC), A. Tekola (SAAO/LGOCT) & the DES survey team*].

Shedding New Light on the Brightest Objects in the Universe:

Quasars are among the brightest, oldest, most distant, and most powerful objects in the universe. Powered by massive black holes at the center of most known galaxies, quasars can emit enormous amounts of energy, up to a thousand times the total output of the hundreds of billions of stars in our entire Milky Way. Dartmouth astrophysicists Ryan Hickox and Kevin Hainline and colleagues have presented the results of an optical spectroscopic survey of a sample of 40 candidate obscured quasars identified on the basis of their mid-infrared emission detected by the Wide-Field Infrared Survey Explorer (WISE). Optical spectra for this survey were obtained using the Robert Stobie Spectrograph on the Southern African Large Telescope. Their sample was selected with WISE colors characteristic of active galactic nuclei (AGNs), as well as red optical to mid-IR colors indicating that the optical/UV

AGN continuum is obscured by dust. They obtained secure redshifts for the majority of the objects that comprise their sample (35/40), and find that sources that are bright in the WISE W4 (22 μ) band are typically at moderate redshift ($< z > = 0.35$) while sources fainter in W4 are at higher redshifts ($< z >= 0.73$). The majority of the sources have narrow emission lines with optical colors and emission line ratios of their WISE-selected sources that are consistent with the locus of AGN on the rest-frame g - z color versus [Ne III]λ3869/[O II] $\lambda\lambda$3726+3729 line ratio diagnostic diagram. They also use empirical AGN and galaxy templates to model the spectral energy distributions (SEDs) for the objects in their sample, and find that while there is significant variation in the observed SEDs for these objects, the majority require a strong AGN component. Finally, they use the results from our analysis of the optical spectra and the SEDs to compare their selection criteria to alternate criteria presented in the literature. These results verify the efficacy of selecting luminous obscured AGNs based on their WISE colors.

Spectroscopic monitoring of high-z SNe
Optical spectroscopy of SNe Ia can provide vital insight into the question of SN Ia diversity. Large samples of SN Ia spectra have been made publicly available, and investigations of spectroscopic subclassification of SNe Ia have been a vigorous area of study. While a rigorous accounting of the diversity of SNe Ia is crucial for understanding the source of their luminosity dispersion, individual cases of well-studied SNe Ia can yield key insights into the nature of the explosions themselves. SALT partners from Rutgers regularly participate in spectroscopic campigns of SNe using RSS/SALT. A very early spectrum of the Type Ia SN 2012fr (14.17 days before maximum light) was obtained by SALT using the Robert Stobie Spectrograph (RSS). This is one of the earliest and highest signal-to-noise spectra ever obtained of a Type Ia SN. Spectroscopic observations of SN CLA11Tib revealed the presence of a strong oxygen emission line from the host galaxy indicating a redshift of z=1.143. Subsequent spectroscopic observations at the VLT confirmed this result.

Scientific Meetings

- **SALT science symposium**

  A one day science symposium on " Recent results from SALT" was held on Wednesday, May 22, 2013 in Nicolaus Copernicus Astronomical Center, Warsaw, Poland. Several people from CAMK and SALT partner institutes participated in this symposium and presented their recent SALT results. [A photo can go here]

- **SALT Science Day: Status updates and recent science results**

  A one day science meeting of SALT partners was held on Monday, 11 November 2013 at North West University, Mafikeng, South Africa. Members and SALT astronomers presented the recent results from their SALT observations. An overview of SALT operations and various statistics related to SALT observations were presented. [A photo can go here]

5. Operations

SALT is an entirely queue-scheduled telescope in which users ("Principal Investigators (PIs)") submit proposals remotely via the internet. PIs therefore do not go the telescope to make observations in the traditional manner. Each partner decides which of their scientists gets access to the telescope and for how much time. This is usually done by a Time Allocation Committee at the partner institution. The PI then sends a detailed "recipe" to SALT Operations which specifies every detail about how to execute the observations.

At night, the telescope is staffed by a "SALT Operator" and a "SALT Astronomer". They execute the recipes from the various PIs in order of priority and constrained by the conditions (cloud, "seeing", brightness of moon etc.). Following successful observations, the acquired data are sent to Cape Town where they are put through an initial calibration "pipeline", placed on an internet website and the PI is notified that the data are ready for downloading.

The telescope is equipped with three first generation instruments and a visitor instrument. This complement includes a low resolution spectrograph with multiple modes (the Robert Stobie Spectrograph or RSS), a high resolution spectrograph (the SALT High Resolution Spectrograph, or HRS), and an imaging camera (SALTICAM) which doubles as the telescope acquisition camera. The visitor instrument is the Berkeley Visible Image Tube (BVIT), a high speed imaging camera supplied by the University of Berkeley in the USA. BVIT was installed and its commissioning completed by 19 February 2013.

Astronomy Operations

The night staff fall under the Astronomy Operations section of the SALT Operations staff. Astronomy Operations is managed by Dr. David Buckley, SALT Science Director.

SALT Astronomers are PhD astronomers who are responsible for executing the science observations. SALT Operators operate the telescope under the direction of the SALT Astronomer.

Since science operations began, operational efficiencies have steadily improved, though this has not always been reflected in program completion statistics. The latter has been compromised by the higher than expected time lost due to weather conditions. During 2013, 212 proposals were awarded time. 55% of the nighttime hours for science were expected; the reality was only 40%. Other causes of less science time (defined as night time less time lost to weather, faults, engineering and instrument commissioning) than expected included higher than anticipated technical faults and more time required for engineering work. During science time, charged science blocks were smaller than expected. This is believed to be mainly due to changing conditions during long exposures, resulting in the need to reject the observation. Proposal completion is also lower than anticipated. This is due to multiple priorities being assigned to each proposal with the lowest priority targets unobserved, exacerbated by the oversubscription of the P3 queue. There are also non-ideal time allocation procedures (being addressed by the partners' Time Allocation Committees (TACs)).

Optimal scheduling observations on SALT is a complex problem and Astronomy Operations staff are steadily improving their understanding of it, but there is some way to go.

Proposal management software at the telescope is vital to efficient observations, as well as support for the proposal submission process. Steady improvements to the suite of this

software have been made throughout 2013. A notable highlight was the inclusion of HRS in all aspects of the proposal management software.

Technical Operations

The engineering side of SALT Operations is the responsibility of the Technical Operations section of SALT Operations. It is headed by Mr. Chris Coetzee.

During the reporting period, the telescope worked reliably on sky, producing science data. Observation time lost due to technical problems, as well as user-induced faults, was 8%. This was mainly due to latent defects after the telescope construction phase, the constant modifications and upgrades required to rectify those defects, adding new functionality to the telescope and fitting and commissioning of new instruments. The nominal target for technical downtime is 3%, which was indeed reached for the month of December 2012. In order to improve the situation the Failure Mode Effect and Criticality Analysis (FMECA) of the telescope was reviewed in the light of many actions already taken to mitigate these risks and new mitigation actions were identified and taken.

The primary mirror fogged over on Sunday 31 March during a prolonged power outage caused by a thunderstorm. The current SALT standby generator does not have the capacity during a power outage to power the glycol system chiller, which is required to keep the conditioning of the dome under control. The SAAO is planning a comprehensive electrical upgrade of the observing plateau. This upgrade will supply sufficient standby power for the chiller and prevent such occurrences in the future. A new process was subsequently put in place to re-coat the segments. This yielded an average rate of 4 segments per week, with some weeks yielding up to 6 segments. The target rate is 2 segments per week. Currently, no segment in the array has gone without re-coating for longer than 40 months.

The apparent faster degrading of the Primary Mirror alignment during open loop operation was investigated and actions taken. These problems will be solved with the new edge sensor (SAMS) and Primary Mirror Alignment System (PMAS).

The coating plants vacuum diffusion pump was replaced since the old one became unserviceable.

Instruments

SALTICAM had to be removed during the reporting period for repairs and modifications of its shutter, filter and focus mechanisms. Work was completed on its commissioning software. Specialised spare parts were defined and the procurement thereof from the SAAO has commenced. Unfortunately, the instrument suffered a condensation event on its optics which damaged the anti-reflection coatings. Fortunately, cleaning of the optics with deionized water recovered the performance.

RSS worked well for most of the reporting period but needed work on PCON, its high level control and configuration management system. Multi-Object-Spectroscopy (MOS) acquisition software was improved, as well as software for better support of the Fabry Perot calibrations.

Technical support was given to many other instrumentation projects such as SAMS, HRS, RSS Collimator repair. The temperature control system for the HRS Thermal Control rooms was completed.

The Tracker Upgrade Project pre-study was completed and the project was approved on 7 March 2013. This project was launched to prepare and upgrade the tracker to accommodate especially the RSS NIR instruments extra weight.

General

An electricity savings project, which was launched during 2011 for the Sutherland site and telescopes, including SALT, has yielded good results for the reporting period. The cost saving, as compared to the 2007 tariffs adjusted by the Eskom increase, was on average 10% lower year-on-year from March 2012.

Personnel issues − the most experienced electronic/electrical technician unfortunately resigned and decided to emigrate to New Zealand with his family. This highlights the ongoing problem of retaining highly skilled technical staff in a remote location with limited options for schooling and family activities.

Health and Safety − no incidents occurred during the reporting period. All technical staff were trained in First Aid, level one, with one staff member reaching level 3.

6. Development

High Resolution Spectrograph (HRS)

One of the highlights for the year was the arrival of SALTs third First Generation instrument, the fibre-fed High Resolution Spectrograph (HRS). The instrument was designed and built by the Centre for Advanced Instrumentation at the University of Durham, who took also responsibility for installing and commissioning the instrument, assisted by SALT operations staff. It was delivered, assembled and integrated with the telescope in the last quarter of 2013. The instrument saw the first light on 28 September 2013. Different modes of the HRS were checked, image quality and throughput tests were repeated. On-sky testing followed by a number of observations were made in various modes. Science verifications observations were taken after fixing various issues that came up during the commissioning observations. The HRS commissioning team (Ray Sharples, Sean Ryan, Lisa Crause, Brent Miszalski & David Buckley) have reviewed the 24 applications received for the science verification program for their suitability. For the first SV period (10 Nov 2013 31 Dec 2014), a nominal 59 hours have been allocated to 17 proposals. Science verification observations began in November, and the combined results to date indicate that the instrument is meeting its design targets, though some final performance parameters are still being verified.

Robert Stobie Spectrograph Visible Arm (RSS)

RSS-Visible has been the main work horse instrument for SALT this year and has been in routine operations for Longslit, MOS and Fabry-Perot observations. One of the most important technical initiatives for the instrument in 2013 has been a project to improve the throughput of the instrument by procuring new optics for the collimator. The instrument control software, PCON and PDET, have been continually improved and many robustness issues have been solved. MOS alignment is now a lot easier and quite efficient. It is now possible to complete all of the MOS set up, including accurate alignment of the slits and fiducials, within 10 mins. There are a few remaining issues that are being addressed: throughput improvements, repairing the polarizing beamsplitter and improving the flat fielding techniques to take care of the moving pupil.

Robert Stobie Spectrograph NIR Arm:

The Robert Stobie Spectrograph Near Infrared Arm (RSS-NIR) has made significant progress in the last year. The instrument is well into the laboratory integration and testing phase. All mechanisms are functional under software control. Higher level software for full instrument configuration is under development. We are in the process of verifying the image quality of the RSS-NIR camera through laboratory bench tests. All preliminary measurements are within specification. The engineering grade detector system has been optimized in a laboratory test dewar. The instrument dewar has passed all vacuum and thermal tests. Detector electronics and a bare multiplexer device are undergoing final tests in the instrument dewar before installing the science grade detector for its final optimization and thermal background tests of the dewar. The pre-dewar enclosure design is nearly complete and will soon be sent out for fabrication, including its CO_2 cooling system. The pre-dewar skin heater system, meant to maintain its outer temperature to within 2 degrees of observatory ambient, has passed all laboratory tests. We are preparing for an outdoor rooftop nighttime test in coming weeks. The laboratory integration and testing phase in Wisconsin is expected to be complete in mid-2015. RSS-NIR will be shipped to South Africa to be integrated with RSS-VIS and installed on the telescope after completion of the tracker upgrade project, likely in early 2016.

Other Significant Development Projects

Good progress was made with the primary mirror edge sensor project (SAMS), following the procurement contract signing in mid-2012. The completion of this project will have a big impact on SALT science performance in the future, improving image quality delivered by the telescope and therefore throughput. This should enable fainter and more distant objects to be observed. Future improvements to a number of SALT subsystems, particularly software, have already born fruit in terms of making the whole SALT observing process more efficient and improving on reducing observational overheads.

7. Education and public outreach activities:

From an educational point of view, SALT's primary role is to provide a platform for astronomical research for the scientists and their graduate students affiliated with the respective partner. In this respect, SALT placed 29 proposals in its observing queue during the reporting period.

From the formation of the SALT Foundation, partners agreed to keep the "Collateral Benefits" activities outside the regular business of the company. Nevertheless, many partners joined SALT as much for these Collateral Benefits as for the scientific access to a large telescope. Thus, although the SALT Foundation does not directly engage in outreach, many of the partners pursue outreach activities, a selection of which include:

- SALT board members participated in visits to schools organised by the North West University after the 2013 November board meeting. SALT members interacted with school children by giving short informal presentations on science with SALT and answered all their questions.

- SALT results featured in weekend outreach events for the general public at Rutgers

Day (April 2013) and for Rutgers Department of Physics and Astronomy alumni (December 2013).

- The presence of SALT in Sutherland has had a significant impact on the town, energetically pursued by SAAO. For example, there are now over 10000 visitors to the telescope are welcomed each year, with a concomitant explosion of more than 30 accommodation establishments springing up in the town and nearby farms. This brings job opportunities and increased economic activity. A computer centre has been established in the town with internet access provided by linking to SAAO.

- The Human Orrery Project with Armagh Observatory, led by Professor Mark Bailey. A Human Orrery is to be built at the Sutherland Schools and at the Observatory.

- Teacher Training and Exchange Programme with the American Museum of Natural History. Resources have been received from Dr Maritza McDonald and have been distributed among teacher organisations and science centres.

- Professor Gordon Bromage and the University of Central Lancashire (UCLan) have made available the distance astronomy courses offered by UCLan to South Africans, particularly teachers and astronomy communication outreach staff.

- SALT Stobie Scholarship: UCLan, University of Southampton and Dartmouth offer scholarships to South African PhD students. Only one applicant was received. Discussions have been held with Professor Bromage, Professor Patricia Whitelock and Dr Stephen Potter (SAAO) to develop new models and approaches to identify good Honours and Masters Students who can be offered these bursaries.

- Collaboration with Space Place of the University Wisconsin continues to develop. The possibility of an astronomy camp has been discussed with Dr Eric Hooper and firm commitment and implementation has to be concluded for 2013.

- Sutherland and Mc Donald Twinning: Discussions on revival of the town twinning project.

- Informal Discussion on Post graduate teacher training with Rutgers University.

- Informal discussions have been held with Polish astronomers on possibilities of collaborations at school level and citizen science.

- Schools have been identified to work with Dr Rick Hessman and the MONET telescope. This will be linked with Dr Carolin Liefkes group of the House of Astronomy in Heidelberg.

8. Corporate Governance

The affairs of the SALT Foundation are regulated by the Shareholderś 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 all 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.

With the exception of Dr Darragh O'Donoghue, all Board members are independent, Non-Executive Directors. In this reporting period, the Board comprised the following members:

Prof Michael Shara (Chair)	*American Museum of Natural History*
Prof Brian Chaboyer	*Dartmouth University*
Prof Gordon Ernest Bromage	*United Kingdom SALT Consortium*
Prof Chris Clemens	*University of North Carolina*
Prof John P. Hughes	*Rutgers University*
Prof Ajit Kembhavi	*Inter University Centre for Astronomy& Astrophysics*
Prof Wolfram Kollatschny	*Göttingen University*
Dr Darragh O'Donoghue	*National Research Foundation*
Prof Larry Ramsey	*Hobby-Eberly Telescope Board*
Prof Roger Reeves	*University of Canterbury*
Prof Marek Sarna	*Nicolaus Copernicus Astronomical Centre*
Dr Albert van Jaarsveld	*National Reseach Foundation*
Prof Eric Wilcots	*University of Wisconsin-Madison*

Other officers of the Company include Mrs. Lizette Labuschagne, Chief Financial Officer, and Mr. Ismail Osman, 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 operations of the telescope also attend the Board meetings.

Operations Contract

In terms of the Shareholders' Agreement, SALT is operated on behalf of the SALT Foundation by the SAAO and managed by the SAAO Director. With the exception of Dr. David Buckley and Dr. Darragh O'Donoghue, the staff who carry out the day-to-day operational activities are SAAO employees. Drs. Buckley and O'Donoghue are the SALT Foundation's only two employees and they assist the SAAO with the execution of the SALT Operations Contract: Dr. Buckley is the SALT Science Director and Astronomy Operations Manager and Dr. O'Donoghue is the SALT Instrumentation Director. Engineering operations are managed by the SALT Technical Operations Manager, Mr. Chris Coetzee.

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

The Board has delegated authority to the Board Executive Commmittee (BEC) to manage the Company during the period between Board meetings. The BEC meets every 6 weeks and receives reports on the operations and development of the telescope from the SAAO Director and other senior staff with the relevant responsibility. The BEC comprises 4 Board members. In this reporting period, they were: Prof. Mike Shara (Chair), Prof. Larry Ramsey, Prof. Brian Chaboyer and Dr. Darragh O'Donoghue.

The Finance and Audit Committee

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 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. Eric Wilcots (Chair), Prof. M. Wybourne, Prof. G. Bromage and Prof. R. Reeves.

The need for strengthening the management of risk at the corporate level has been recognized. Accordingly, a 1-day retreat prior to the 2013 November Board meeting took place and was led by the Dr. Thomas Auf der Heyde of the South African Dept. of Science and Technology. Strategic objectives of the Company were formulated and included preliminary discussions of managing the risks of not meeting the objectives. SALT is very grateful to Dr. Auf der Heyde for his input in this process.

9. List of Publications

Refereed Publications

1. Catala, L., Crawford, S.M., Buckley, D.A.H., et al., 2013, "Optical turbulence characterization at the SAAO Sutherland site", MNRAS, 436, 590.

2. Childress, M.J., Scalzo, R.A., Sim, S.A., et al., 2013, "Spectroscopic observations of SN 2012fr: A luminous, normal type Ia supernova with early high-velocity features and a late velocity plateau", ApJ, 770, 29.

3. Czerny, B., Hryniewicz, K., Maity, I., et al., 2013, "Towards equation of state of dark energy from quasar monitoring: Reverberation strategy", A&A, 556, A97.

4. Feast, M.W., Menzies, J.W., Whitelock, P.A., 2013, "A carbon-rich Mira variable in a globular cluster: a stellar merger", MNRAS, 428, L36.

5. Gvaramadze, V.V., Menten, K.M., Kniazev, A.Y., et al, 2013, "IRC - 10414: a bow-shock-producing red supergiant star", MNRAS, 437, 843.

6. Hainline, K.N., Hickox, R., Greene, J.E., et al., 2013, ' 'SALT long-slit spectroscopy of luminous obscured quasars: An upper limit on the size of the narrow-line region?", ApJ, 774: 145.

7. Kilkenny, D., Welsh, B., Koen, C., et al., 2013, "A search for p-mode pulsations in white dwarf stars using the Berkeley Visible Imaging Tube detector", MNRAS, 437, 1836.

8. Kniazev, A., Vaisanen, P., Muzic, K., et al., 2013, " Characterization of the nearby L/T binary brown dwarf WISE J104915.57 - 531906.1 at 2pc from the Sun", ApJ, 770, 124.

9. Milisavljevic, D., Margutti, R., Soderberg, A.M., et al, 2013, "Multi-wavelength observations of supernova 2011ei: time-dependent classification of type IIb and Ib supernovae and implications for their progenitors", ApJ, 767, 71.

10. Miszalski, B., Mikolajewska, J., Udalski, A., 2013, "Symbiotic stars and other Halpha emission-line stars towards the Galactic bulge", MNRAS, 432, 3186.

11. Miszalski, B., Boffin, H.M.J., Jones, D., et al., 2013, "SALT reveals the barium central star of the planetary nebula HEN 2-39", MNRAS, 436, 3068.

12. O'Donoghue, D., Crause, L.A., Strumpfer, F., et al., 2013, "Resolving the Southern African Large Telescope's image quality problems", Optical Engineering, 52, 8. 081604.

13. Sturm, R., Haberl, F., Oskinova, L.M., et al., 2013, "Long-term evolution of the neutron-star spin period of SXP 1062", A&A, 556, 139.

14. Todt, H., Kniazev, A.Y., Gvaramadze, V.V., et al., 2013, " Abell 48 - a rare WN-type central star of a planetary nebula", MNRAS, 430, 2302.

15. Tofflemire, B.M., Orio, M., Page, K., et al., 2013, "X - Ray grating observations of recurrent niva T Pyxidis during the 2011 outburst", ApJ, 779, 22.

16. Ulusoy, C., Niemczura, E., Ulas, B., Gulmez, T., 2013, "An asteroseismic study of the southern beta cephei star ALS 3721", New Astronomy, 22, 51.

17. Ulusoy, C., Niemczura, E., Ulas, B., Gulmez, T., 2013. "New β Cephei variable in the Southern open cluster NGC 6200: ALS 3728", New Astronomy, 23, 55.

Non-refereed publications

1. Buckley, D.A.H., 2013, "Selecting, scheduling and carrying out observing programmes at SALT. Organizations, People and Strategies in Astronomy", Volume 2 (OPSA 2), p. 275, ed. A. Heck. Venngeist, Duttlenheim.

2. Charles, P.A., 2013, "Status of SALT, and joint science projects with GTC", Rev. Mex. Astron. Astrof. Ser. Conf., 42: 96.

3. Czerny, B., Hryniewicz, K., Kaluzny, J., Maity, I., 2013, "Dusty origin of the broad line region in active galaxies. Feeding compact objects", IAU Symp. 290, p. 21, eds. C.M. Zhang, et al. Cambridge University Press, Cambridge.

4. Malgorzata Bankowicz, "Poszukiwanie najodleglejszych gigantycznych radiozrodel z uzyciem teleskopu SALT" 2013, master thesis, supervisor dr Dorota Kozie-Wierzbowska (Search for the most distant giant radio sources using SALT)

Telegrams

1. IAUC Electronic Telegram No. 3635 - SUPERNOVA 2013ex IN NGC 1954 V. Pandya, S. W. Jha, C. McCully, and B. Patel, Rutgers University; Y. Camacho, Lehigh University; and P. Vaisanen, Southern African Large Telescope (SALT) and South African Astronomical Observatory

2. ATel #5142 - Optical Spectroscopy of iPTF13bvn D. Milisavljevic (Harvard-Smithsonian Center for Astrophysics, (CfA)), R. Fesen (Dartmouth College), T. Pickering, B. Miszalski (South African Astronomical Observatory (SAAO) and the Southern African Large Telescope (SALT)), D. Buckley (SALT), J. Parrent (Dartmouth College and Las Cumbres Observatory), G. H. Marion, J. Silverman, J. Vinko, C. Wheeler (UT Austin), R. Quimby (Kavli IPMU), S. W. Jha (Rutgers), S. Mohamed (SAAO), M. M. Kasliwal (OCIW & Princeton), and A. Soderberg (CfA)

3. IAUC Electronic Telegram No. 3393 - SUPERNOVA 2013M IN ESO 325-G43 = PSN J13595668-3751494 S. W. Jha and C. McCully, Rutgers University; A. Kniazev, South African Astronomical Observatory and Southern African Large Telescope; E. Hsiao, Las Campanas Observatory; and G. H. Marion, Harvard-Smithsonian Center for Astrophysics