SALT Newsletter

December 2023

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Editor: Anja C. Schröder

Cover image: Snowy SALT . -- *Credit*: Kevin Crause

Letter from the Head of Astro Ops

Dear SALT Community,

As our summer holiday season approaches, the weather at the telescope is finally improving, after having suffered our worst ever weather loss since the start of SALT Operations during the last semester (2023-1, at just under 53%). On top of this, we had a few technical problems, including our instruments: we lost SALTICAM for 10 weeks due to cooling problems, and RSS followed soon after, leading to lower programme completion than anticipated. More details on what happened to both instruments below. But the good news is that we seem to be over the hump: SALTICAM is back on the telescope, RSS is behaving well (mostly), we've finally started to use our new longslits (see below), as mentioned above the weather has picked up, and we've finally started taking science observations for the NIRWALS instrument team! In fact, we have set aside 30 hours of SALT time during semester 2024-1 for NIRWALS science proposals from the community on a shared-risk basis — for more details, please read the full Call on our website: https://astronomers.salt.ac.za/

Continuing with the good news, the LFC team visited us again in November/December for phase 2 of the installation. Unfortunately, they suffered a temporary set-back with the laser, but we expect completion of the project early in the new year — read all about it from Lisa below.

The new optical slitmask IFU for RSS is nearly ready to go on-sky and begin commissioning. This is an array of 18”x23” fibres of 0.9” diameter, with sky bundles at ±50” centre to centre. Sabyasachi gives us a great summary of the status and plans below.

A sad bit of news from our side is that at the end of March we will be saying goodbye to our pipeline SALT Astronomer, Enrico Kotze. During his time with us, amongst many other things, he has made huge improvements to our primary pipeline, developing an RSS science data reduction pipeline and has been working tirelessly on the NIRWALS pipeline, all of which we hope will be essentially finished before he leaves us to travel the world. The advert for his replacement will be out imminently, deadline end of January, on our website and on the AAS Job Register — if you think you have what it takes to fill his boat-sized shoes and join our team, or know someone who does, please get in touch and/or look out for the advert! ☺

Wishing you a wonderful holiday season and that Santa brings you lots of excellent-quality SALT data taken under perfectly clear skies with sub-arcsecond seeing,

Clear skies and stay safe!
Encarni

SCIENCE HIGHLIGHT

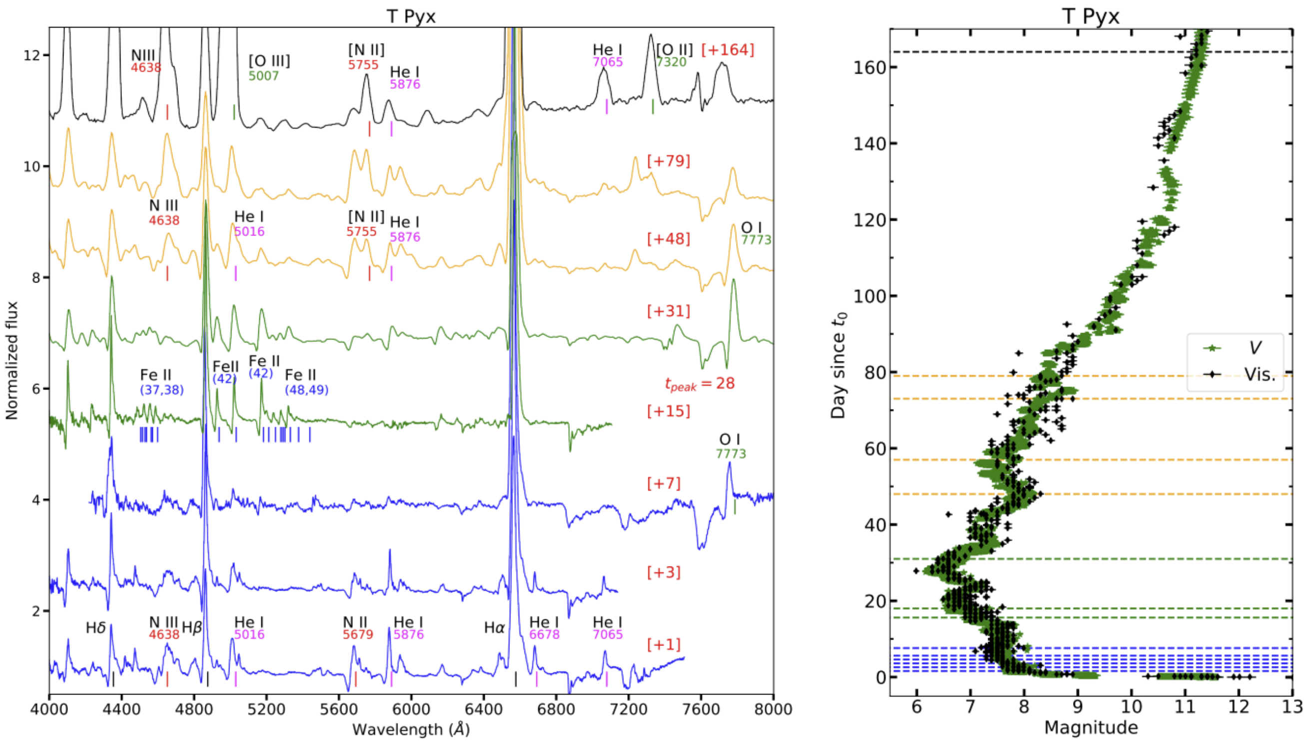
Revisiting the classics: On the evolutionary origin of the "Fe II" and "He/N" spectral classes of novae

by Elias Aydi (Michigan State University, USA)

Classical novae, transient thermonuclear runaway events on the surfaces of accreting white dwarf stars, are some of the brightest and most common transient events in our Galaxy (10 to 15 are discovered in the Milky Way per year). They reach a peak brightness between 13 and 1 magnitude in the visible, which makes them ideal targets for ground-based spectroscopy since the first half of the 20^{th} century. Optical spectra of novae near peak brightness are dominated by emission lines or P Cygni profiles, with the strongest being of the hydrogen Balmer series, in addition to *either* low-ionisation Fe II lines *or* high-excitation He and N lines. This led to a historic classification of novae into two classes: "Fe II" and "He/N" spectral classes, based on the features observed in their optical spectra near peak. More recent studies in the past two decades revealed that some novae show features from both spectral classes simultaneously, or even transitioning from one class to another, dubbing them "hybrid" novae. Pioneering studies by R.E. Williams suggested that all novae might be hybrid, while S.N. Shore suggested that the same nova could show an evolution from one class to another depending on the conditions within the novae ejecta (*i.e.*, changes in opacity, ionisation, density). That is, Fe II novae are the ones which are observed during a time when the ejecta are optically thick, while He/N novae are the ones which are observed during a time when the ejecta are optically thin.

In our recent study, we revisit these pioneering studies to settle the debate about the Fe II and He/N spectral classes of novae, backed up with modern spectroscopic data covering the evolution of a large sample of novae from *early rise* to *peak* all the way to *the nebular phase*. This was made possible by the agility of telescopes like SALT and SOAR in addition to the contribution from professional astronomers and citizen scientists. The rapid response of these telescopes allowed us to capture several novae during their rise to peak — even for the fastest ones, which climb to peak in less than a day. This allowed us to observe early and critical stages in nova evolution that is often missed. Our data show that *all* novae, whether they evolve rapidly (rising to peak brightness in a few hours and declining by several magnitudes in a few days) or evolve slowly (rising to peak brightness in few days/weeks and declining by a few magnitudes over months), go through at least three spectroscopic phases as their eruptions evolve: an early He/N (phase 1, observed during the early rise to visible peak and characterised by P Cygni lines of He I and N II/III), then an Fe II (phase 2, observed near visible peak and characterised by P Cygni lines of Fe II and O I), and then a later He/N (phase 3, observed during the decline and characterised by emission lines of He I/II, N II/III), before entering the nebular phase, where nebular and auroral lines dominate the spectrum. The figure highlights this evolution for one of the novae in our sample.

This evolution of early He/N → Fe II → late He/N seems to be ubiquitous to novae with the only difference being the timescale of these phases. Fast evolving novae which are traditionally classified as He/N novae, are often first observed during the late He/N phase, because the first two phases are often missed given that they only last for a few hours/couple of days. Only rapid spectroscopic follow up, made possible by agile telescopes like SALT, allowed us to capture these novae during these early phases. Slow novae, which are traditionally classified as Fe II novae, are often observed during the Fe II phase, which could last for several weeks. Our dedicated spectroscopic follow-up for a large sample of novae settled the debate about the spectral classes of novae, confirming that they are stages in the spectral evolution of a nova — an evolution that is common to all novae.



Left: The overall spectroscopic evolution of nova T Pyx, representing the different spectral stages: phase 1 (early He/N, highlighted in blue); phase 2 (Fe II, highlighted in green); phase 3 (late He/N, highlighted in orange); and the nebular phase (highlighted in black). Numbers in brackets are days after t_0. Tick marks are presented under the lines for easier identification; they are colour coded based on the line species. *Right*: The optical light curve of nova T Pyx. The blue, green, orange, and black dashed lines representthe spectroscopic epochs for when the nova was in phase 1 (early He/N), phase 2 (Fe II), phase 3 (late He/N), and the nebular phase,respectively.

Published as Aydi et al. (2022), MNRAS (accepted), https://arxiv.org/abs/2309.07097.pdf

Salticam repairs

Salticam (SCAM) is the SALT acquisition camera and has come a long way in the history of SALT. The instrument has been running very reliably until mid-September, when we started seeing cooling issues. We monitored the cooling and found that we were losing refrigerant from the cryo cooler system. The PT30 gas that is used in the cryo cooler cannot be detected by the normal halogen leak detectors, so we ordered a butane, methane and propane leak detector to find the offending leak. On 20 September, we received the leak detector and we found the leak on one of the cryo hoses inside the rho wrap on the tracker.

We had a cryo hose failure in the previous rho wrap before the tracker upgrade was done. At that time, the overall opinion on the break was that the rho wrap radius was smaller than the allowable cryo pipe bend radius, and the rho wrap was over populated. With the new wrap design, the wrap radius was changed to the allowable cryo pipe bend radius and each one of the compartments had only one pipe in a compartment. We found out afterwards that we still had some mitigation to implement, if we wanted to prevent similar breakdowns. We now tried to swop pipes around with a used spare, but found that the used spare was no good. At this stage, the bad news was given to the astronomers. We managed to stretch the amount of time that we could still use SCAM to the limit while the pipes were on order from Edwards in America.

In the meantime, BCam was installed and we cleaned the SCAM optics, replaced the shutter and performed a service on the instrument. The long stainless steel pipes up the structure leg and the piping inside SCAM to the cold end in the cryostat were vacuumed and re-charged with PT30.

When we received the new cryo pipes from Edwards, the pipes were installed on Friday, 24 November. On Monday, 27 November, we were still not completely happy with the vacuum on the structure leg pipes, but we had everything prepared for installation of SCAM for Tuesday. Tuesday was the big day and the instrument was successfully installed and the cryo cooler system worked perfect the first time around.

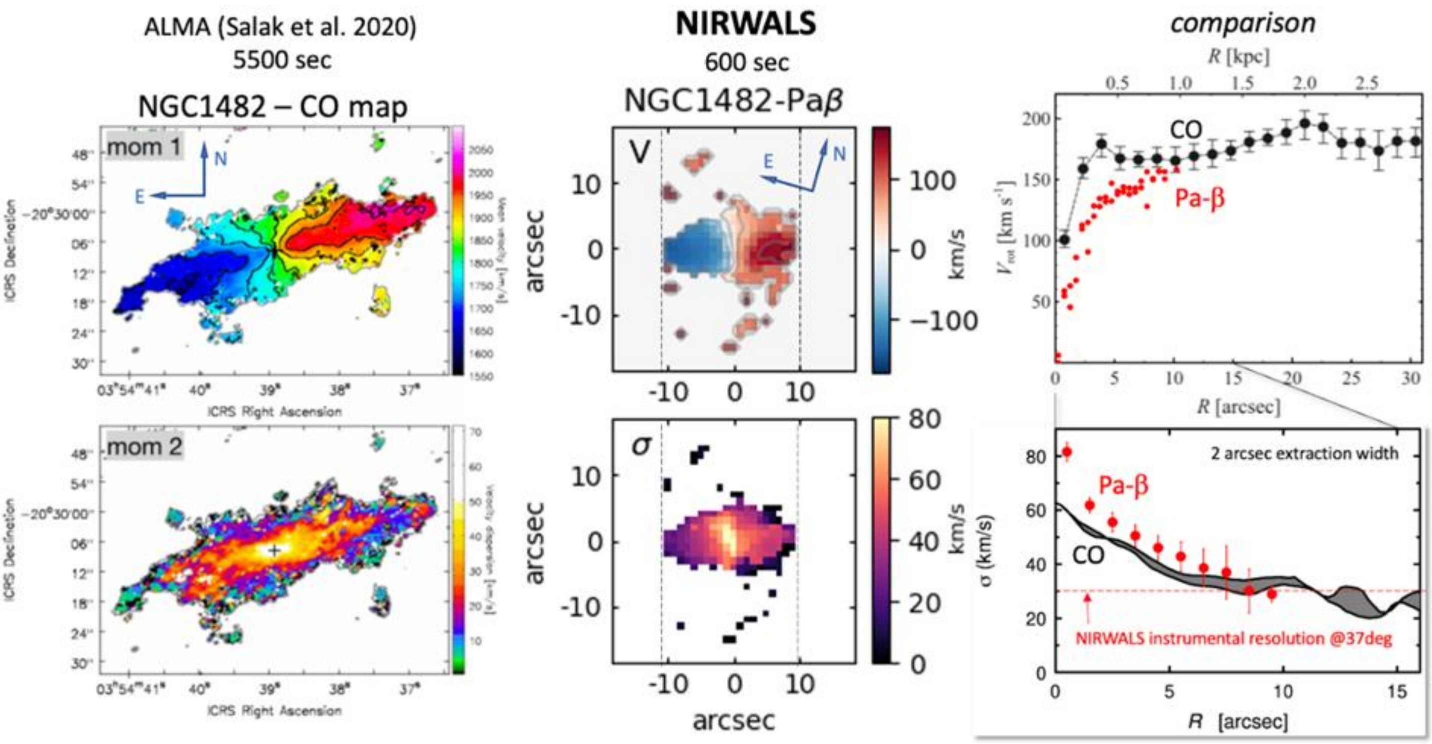
SCAM was never the all-time favourite instrument on SALT, but after the astronomers have been working with BCam for several weeks, there was a complete newly found appreciation for this old work horse! Well done SALT technical staff for getting SCAM back on sky!

With the current pipe configuration, we moved the lengths of the pipes around to have a sacrificial shorter length of cryo hose through the rho wrap. This supply and return length of hose will be replaced every five years, and the other cryo hoses that run through the X and Y wraps were re-routed to run through the bigger radius outer wraps. This bigger radius, which is at least three times the allowable bend radius of the hoses, will effectively stretch out the lifetime of these hoses by a long shot.

Eben Wiid.--

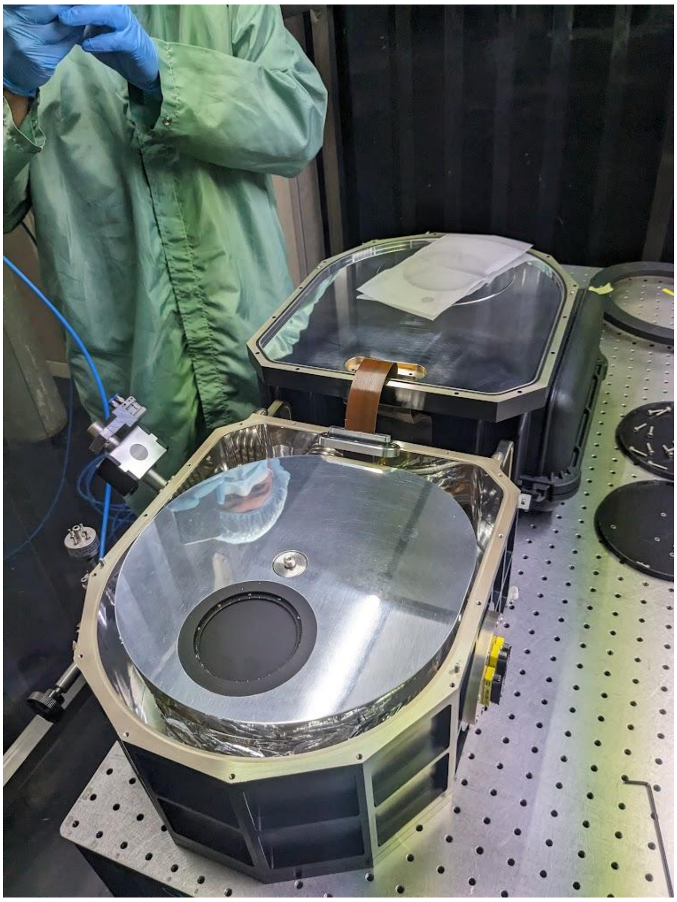
NIRWALS is ready for shared risk science observations

The final NIRWALS science commissioning data were collected throughout July to November 2023. These observations were designed to characterise all remaining aspects of instrument performance and to optimise operation within the observatory, culminating in science verification observations of objects with data in the literature to which NIRWALS data can be compared. An example is shown below for the ULIRG galaxy NGC 1482. These maps were generated using code developed by Antoine Mahoro (SAAO) and Matt Bershady (UW/SAAO) that generates data cubes from NIRWALS reduced row-stacked spectra.

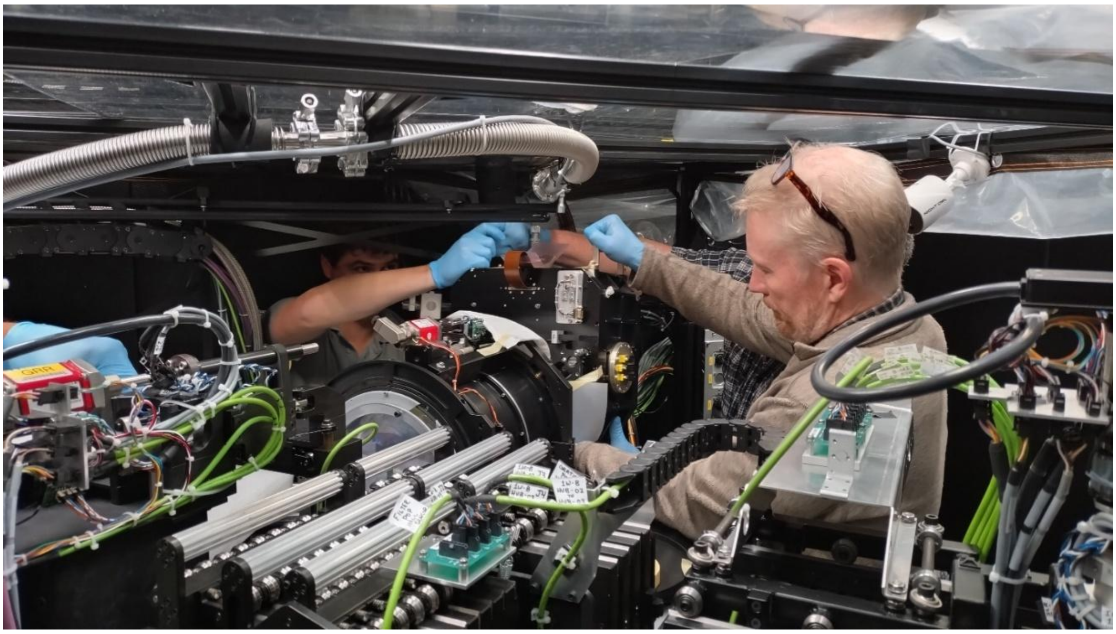


Moment maps (*top row*: velocity, *bottom row*: dispersion). The *left* column presents ALMA CO (J=1→0) moment maps from Salak et al. (2020). The *middle* column presents the NIRWALS Pa-β maps made from a single 600 sec exposure. Note the horizontal extent of the NIRWALS data representing the limit of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

Two members of the UW instrument team, Mike Smith and Marsha Wolf, traveled to SALT in November 2023 for a (final?) instrument servicing mission. The work performed included (1) replacement of the camera focus mechanism with a slightly redesigned and ruggedised version for better operation in the cold operating temperature, (2) repair of the camera articulation mechanism (some too-short screws in the locking detent had worked their way loose), (3) installation of a new long wavelength cutoff filter inside the cryogenic dewar to improve thermal backgrounds by blocking any light beyond 1.7 microns, and (4) a modification of the mounting of the object and sky fibre bundles in the Fibre Instrument Feed (FIF). The NIRWALS fibre bundles will now operate similar to HRS fibres with the object bundle at the field center and the sky bundle offset by a specified field distance from that.

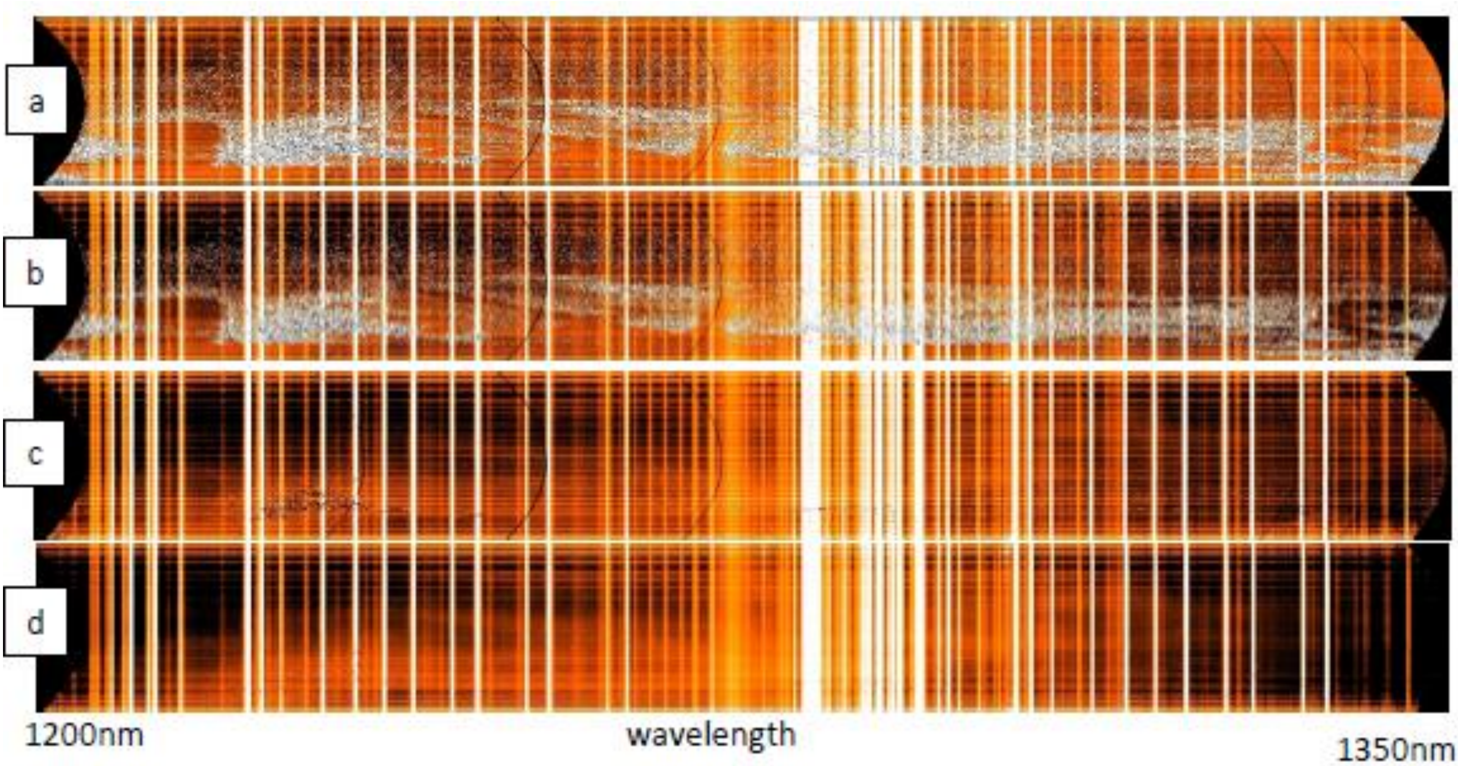


The NIRWALS cryogenic dewar opened up in SALT's cleanroom tent for installation of the new long wavelength cutoff filter.

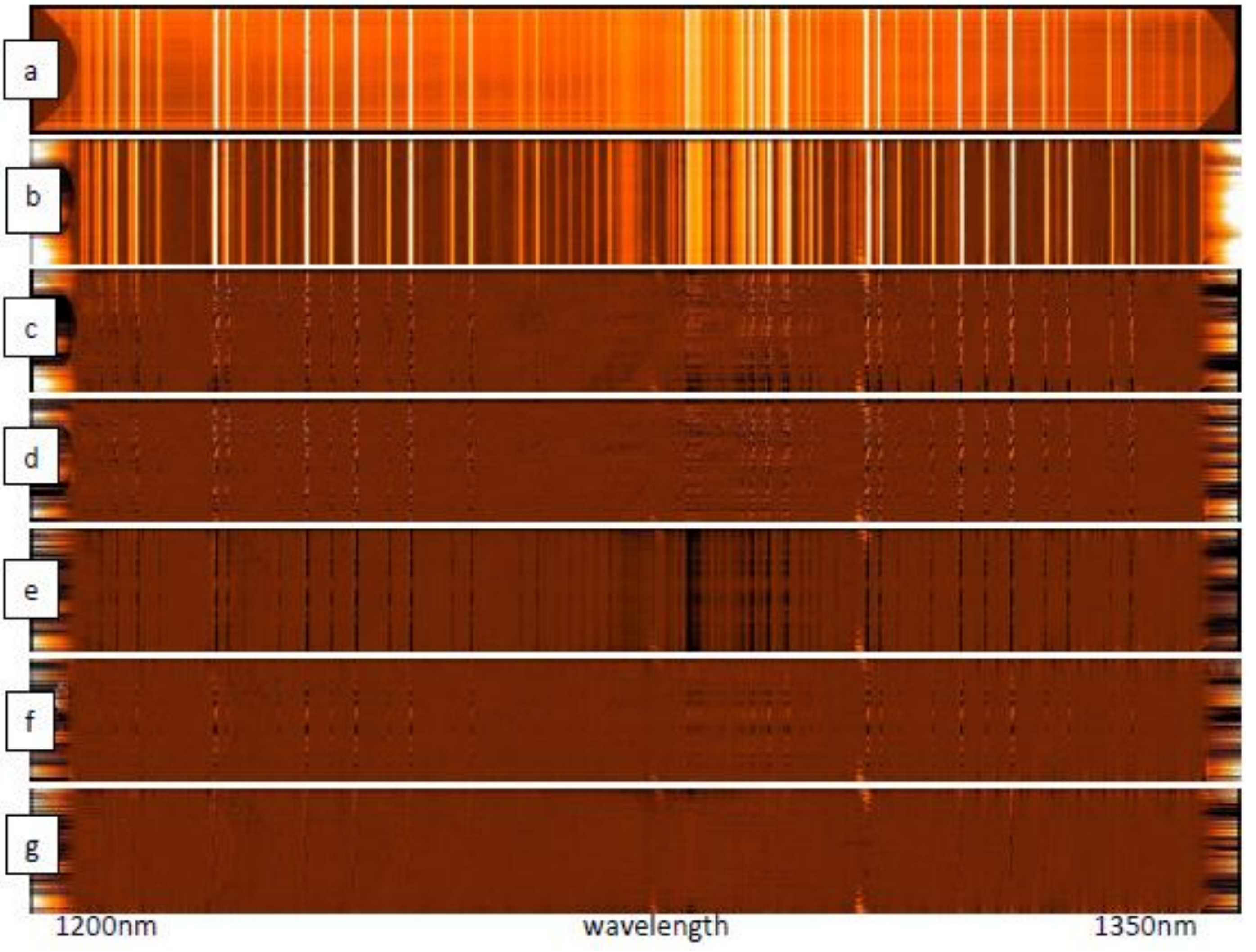


Mike Smith, Nico van der Merwe, and Eben Wiid reinstalling the NIRWALS cryogenic dewar into the spectrograph.

Previous issues of the newsletter mentioned the detrimental impact of SALT's changing illumination pattern on the ability to use the NIRWALS sky bundle as designed for accurate sky subtraction. SALT Optical Engineer Melanie Saayman is conducting an exercise to precisely model the SALT focal plane illumination, with the ultimate goal of predicting the illumination pattern (the flat field) for any given track. This effort will benefit not just NIRWALS but all instruments on SALT, though it will take some time to complete. In the meantime for NIRWALS, Matt Bershady has formulated a way to use the sky emission lines themselves to 'flat field' the data and perform sky-subtraction. The process requires a separate blank sky observation, rather than using fibres in the sky bundle, to sky-subtract the spectra. His spectral reduction package was developed in IRAF and has been ported to Python by SALT Astronomer Enrico Kotze. Examples of the reduction steps are shown below.



Impact of bad pixels and uncalibrated, non-uniform illumination in extracted spectra: *The display contrast and stretch is identical in all images*. (a) IRAF/dohydra extraction of spectra from the 2D data frame, with no removal of bad pixels and use of the CalSys quartz-flat to correct response; (b) with dark-subtraction before extraction; (c) with dark-subtraction and bad pixels masked before extraction; (d) as (c) but without using the quartz-flat. **Note:** (i) There is only modest change after dark subtraction (a to b), but dramatic change after masking bad pixels (from b to c). (ii) There is significant further improvement when eliminating the quartz-flat (c to d) due to noise and non-uniform illumination. Close examination of (c) and (d) reveals systematic differences in the continuum levels for object and sky fibres in (c) that are not present in (d). This is due to differences in illumination of these fibres by the sky flux versus the CalSys quartz lamp. *There is no facility data readily available to correct for this illumination mismatch.*



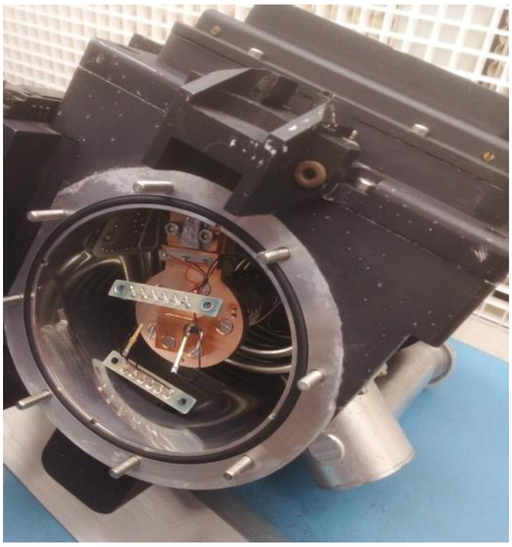
Sky-subtraction steps after processing in IRAF via dohydra to produce extracted and wavelength-rectified row-stacked spectra. *The display contrast and stretch is identical in all images*. From top to bottom: (a) Initial extracted object frame, consisting of a single 600 sec exposure between 1200 – 1350 nm (*J*-band, grating angle 37 deg) of NGC 1482, a ULIRG with the morphology of a high-inclined spiral galaxy with a dusty disc; (b) continuum-subtracted spectra; (c) line-subtracted spectra using a 1st-order polynomial fit (a constant) with 3s iterative rejection; (d) line-subtracted spectra using a 5th-order Legendre polynomial function; (e) continuum-subtracted object row-stacked spectra minus temporally-adjacent row-stacked spectra of blank sky; (f) the same as (e) but with the sky spectra scaled by a wavelength-dependent factor to account for sky-intensity variations; the factor is constant for all fibres; (g) the same as (e) and (f) but also including a time and fibre-dependent illumination and throughput factor constant with wavelength. The two sets of emission-lines seen after line-subtraction are [Fe II] λ1.257µm and Pa-β. The ratio of [Fe II] / Pa-β is a powerful spectral diagnostic distinguishing shocked gas from gas ionised from photo-ionisation by stars or AGN, and is now commonly used in high-redshift studies using JWST. Just from these line-ratios we can conclude this gas is not shock-heated. Determining whether the photo-ionisation is due to stars or AGN requires analysis of accompanying *Y*-band data of He I and Pa-γ lines; quick inspection of these data indicates consistency with starburst photo-ionisation.

NIRWALS is ready to begin shared risk science observations and will be included in the proposal call for the SALT 2024-1 observing semester.

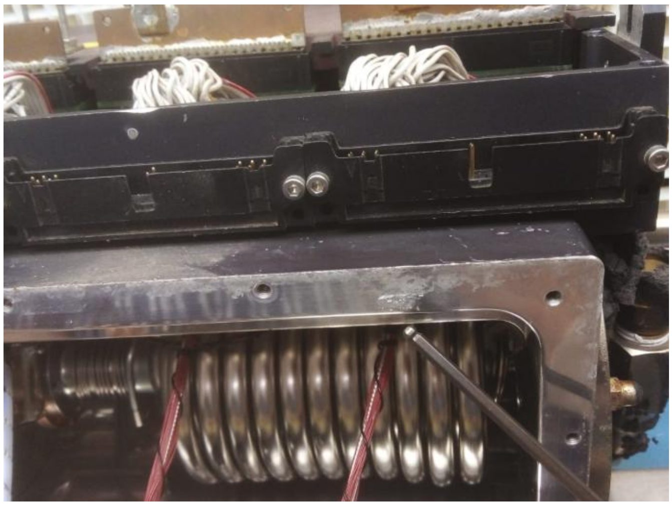
Marsha Wolf.—

Unscheduled RSS cryostat maintenance

During the final week of October, a problem was identified with the RSS cryostat that required it to be warmed up and the vacuum pumped down. Unfortunately, soon after the re-cooling process was complete, we noticed a leak somewhere on the cryostat. Despite valiant efforts over the next two weeks to repair the leak *in-situ*, the team was unable to fix the problem. The leak was traced with the RGA (a leak detection system known as a residual gas analyser) using helium gas. The decision was then made to remove the RSS cryostat from the instrument on 13 November. It was taken back to Cape Town that night for surgery in the SAAO CCD laboratory.



Cryostat end cover removed to loosen the braid that connects the cold end to the CCD.



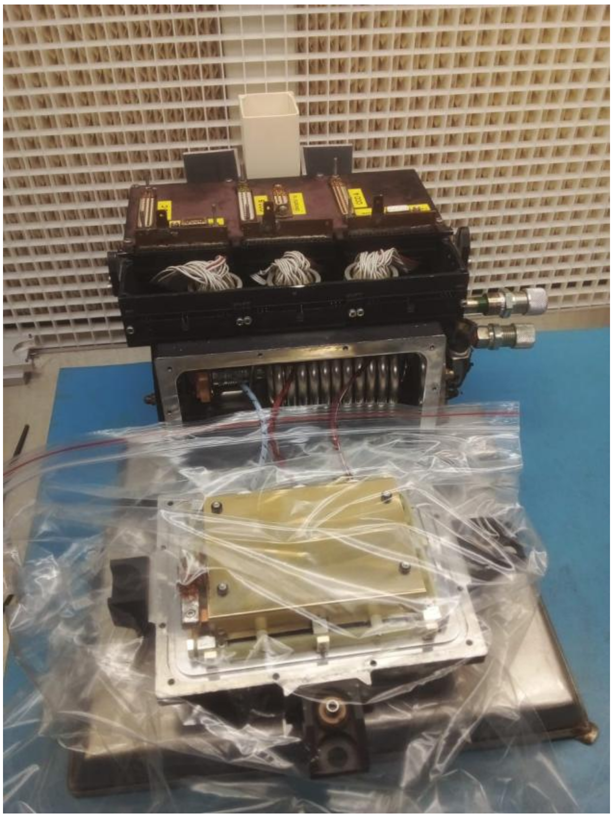
CCD front mounting plate removed. Note the oxidation spot on the cryostat sealing surface, where the allen key is pointing to.

To help the team to repair the cryostat, Willie Koorts generously offered his assistance for the week. Willie and Eben Wiid quickly identified a corroded sealing surface on the cryostat after the front cover was removed. The corroded aluminium surface on the cryostat would not seal even if a new o-ring was installed. The surface was polished using a custom made sandpaper holder thingamagic with dry 1500 and 2000 grit sand paper without using any foreign liquid or polish. Lastly the surface was burnished by using the underside of the 2000 grit sand paper. New o-rings and a new ion pump were also procured, prepared and installed during the week in Cape Town. The o-rings were washed, dried and then vacuum baked overnight before they were installed. New o-rings were installed on the front CCD mount plate, the round side cover and the ion pump mount. The activated carbon and holder was vacuum baked overnight at 250^{o}C, and we tested the repaired surface vacuum integrity before the carbon was installed, just in case we had to come back and do a little more polishing. We were happy to find that our first fix did the job, and that the RGA showed no leak on an initial vacuum on the cryostat. The end cover was removed again and the carbon was installed from the nitrogen filled bell jar after the vacuum baking.

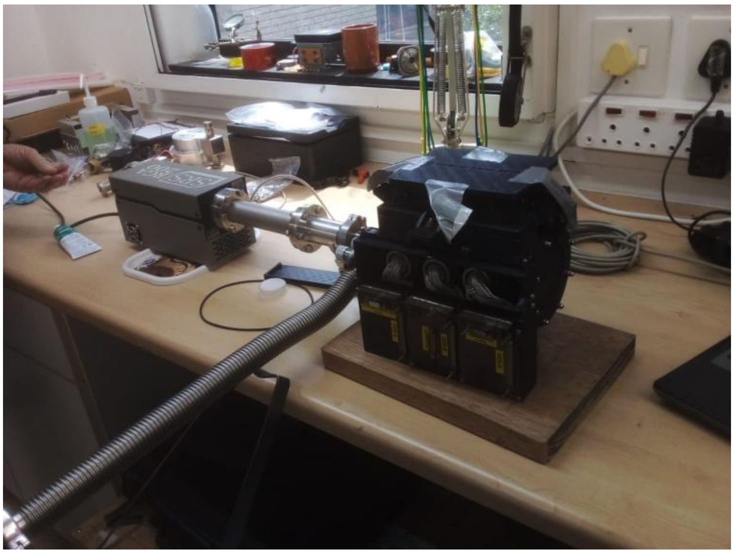
The cryostat was reassembled on 16 November, just three days after being taken off the telescope. No leak could be identified after the cryostat was put under vacuum, so it was baked at 45^{o}C overnight, while the vacuum pump was still connected. The next morning, Eben and

Etienne put the RGA back on the cryostat for a sanity check and purged helium all around the patient. No leaks were found, so the cryostat was packed and started its journey back to Sutherland just after 07:00 on Friday morning. The cryostat was installed on RSS on Friday afternoon, 17 November, and the tests were run during the night to determine how much adjustment was needed for the CCD alignment. The alignment was found to be almost perfect and RSS was available for science the next night.

All together, RSS spent just five nights offline, being operational again on the night of 18 November, thanks to a precise installation and alignment back on the telescope. In the ~3 weeks since reinstallation, the vacuum has held well. However, the cold-end temperature has warmed up on a few occasions, requiring minor intervention by Tech-Ops; essentially a brief turning off and on of the cryo cooler. At the time of writing, this is still an intermittent problem and is being monitored closely. At least we can say that the vacuum problem was definitely overcome by a great team effort from all involved. We want to say a very special thanks though to Willie Koorts, who is always a pleasure to work with, and whose knowledge and skills are just amazing!



The re-surfaced cryostat ready for a new o-ring seal.



RSS Cryostat re assembled and under vacuum with the RGA connected to check the vacuum integrity after the fix.

Lee Townsend & Eben Wiid.--

RSS longslits

The current stage of the RSS longslits project is the identification of the key parameters, which contribute to telescope performance, namely reflectivity/flatness and slit straightness. We have surveyed (or audited) the existing set of longslits to determine their accuracy levels as a basis to understand what is possible. We have investigated various manufacturing possibilities to meet the requirement specification at a practical level. We also have manufactured multiple sets of prototypes (with two external suppliers and the SAAO workshop), with the aim to demonstrate the manufacturing process and have the finished item validated (that is, tested by Astro-Ops).

It was found that the two external suppliers used for some of the prototypes were unable to achieve the desired tolerance levels. The SAAO workshop has spent extensive development efforts to perfect the manufacturing process, since multiple processes are required to manufacture these longslits.

In addition, proper measurement of the slit has proven to be particularly challenging. In response to this difficulty, the SAAO workshop procured a high resolution video measurement machine (capable of measuring 2-D profiles rapidly), which is now used frequently to assess the quality of the slits before being sent out to the telescope for validation testing.

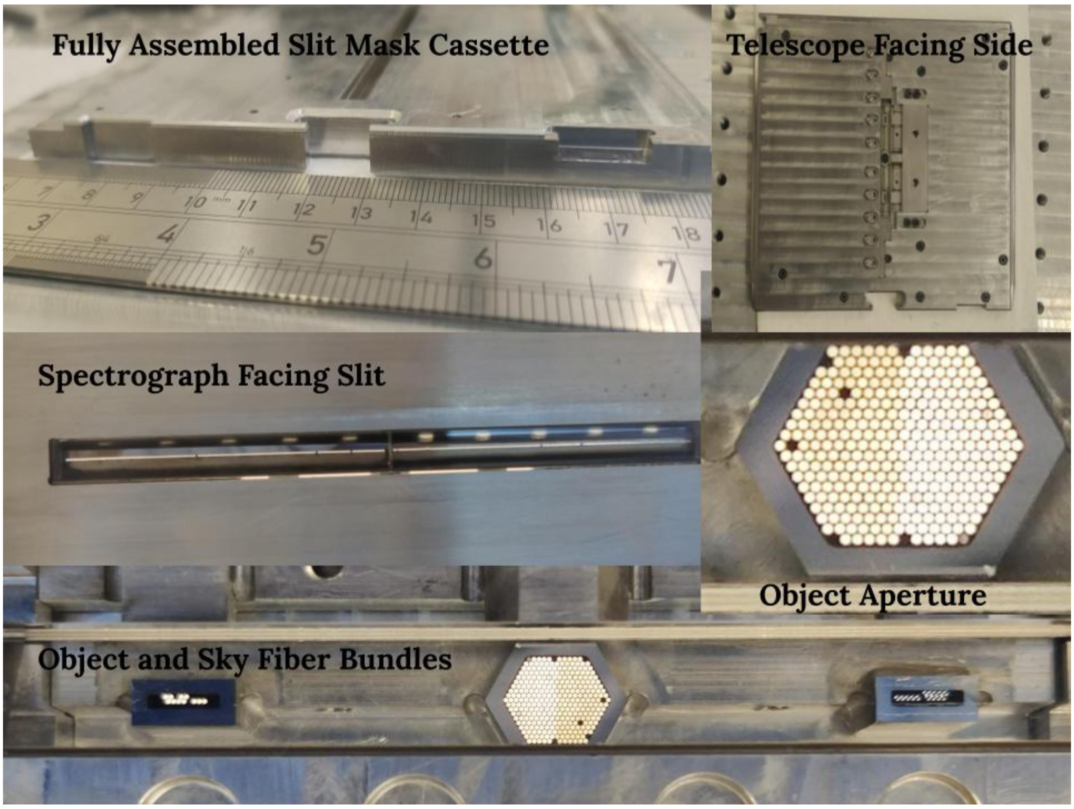
Based on favourable feedback from SAAO prototypes, which were extensively tested by Astro-Ops, we are currently doing ‘production’ of what will be the final set of slits. We are aiming for 20 in total, including a number of spares.

Tasheen Naicker.--

Slit mask integral field units for the RSS

The first of three fibre integral field units (IFUs) is being lab calibrated in the SAAO fibre-lab for the RSS's visible arm. Each sits in its own slit-mask cassette and is referred to as a slit-mask IFU (SMI). These will be insertable in the same fashion as the existing long-slit cassettes at the SALT focal plane. Prismatic fold mirrors direct the focal plane into the fibre IFU and then back into the RSS collimator after the fibres are routed 360 degrees within the cassette and formatted into a pseudo-slit. We aim to install the 200 micron (0.9 arcsec sampling, 18 x 23 arcsec field) version in early 2024. This IFU version has 336 spatial resolution element out of which five have lower throughput but none are broken. The rest of the fibres show throughput uniformity within ±2%.

At this time, we have fully assembled and integrated the components, and a rigorous laboratory characterisation is ongoing to measure throughput as well as focal ratio degradation of all fibres. The SMI exterior mechanical cassette is tested on the RSS cartridge-elevator-letterbox mechanism to ensure mechanical integrity and the longevity of the optical surfaces. Using the SAAO fibre-lab state-of-the-art optical metrology and characterisation system, we found that the polished fibres have about 60% ± 2% throughput at the SALT focal ratio of f/4.2, while the total throughput is about 83%. We have also achieved stability of the SALT focal plane after the introduction of the SMI. Over the coming semester, we plan to perform science commissioning along with delivering a data processing pipeline. In addition to this, we have started fabricating the 300 µm (1.35 arcsec) version of the SMI, which will mimic the footprint of NIRWALS to enable wavelength panorama.



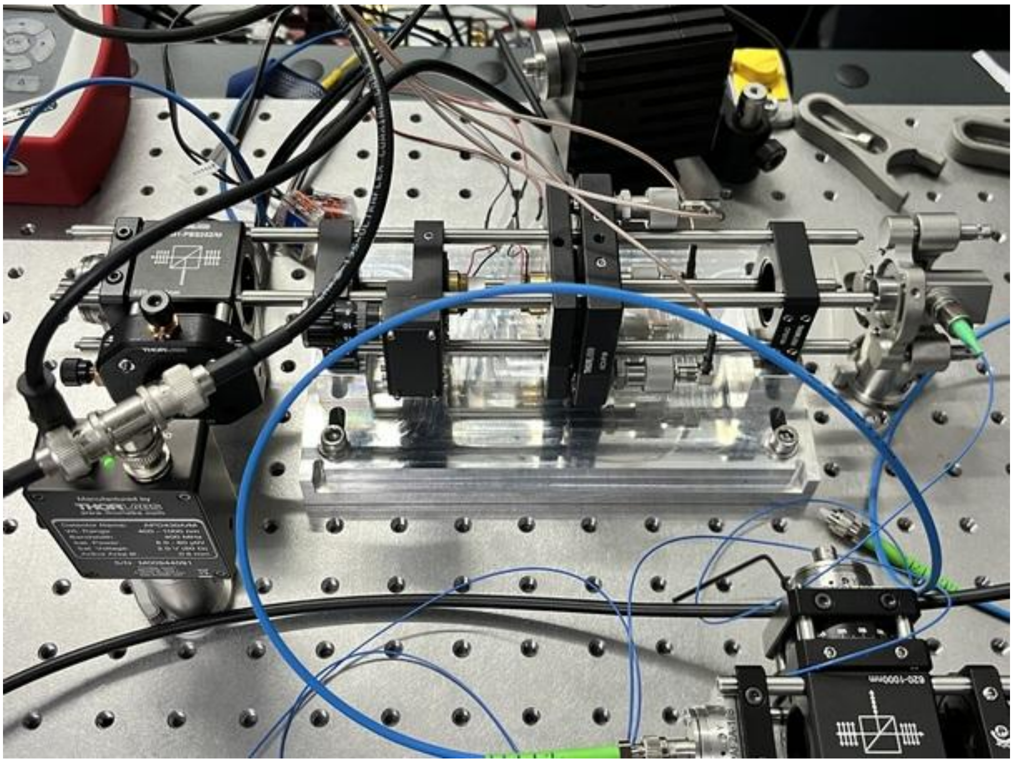
Sabyasachi Chattopadhyay.--

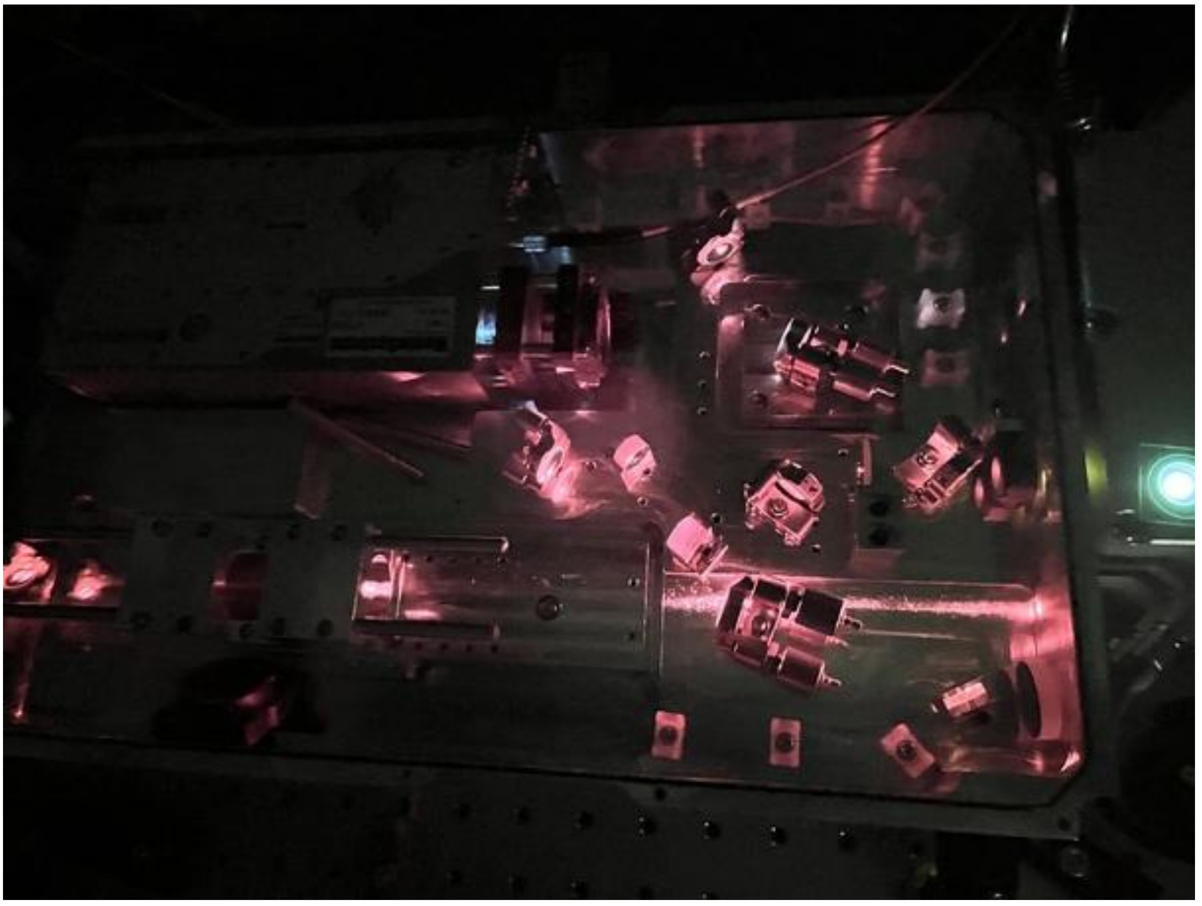
Phase II of the SALT laser frequency comb installation

Laser physicists Richard McCracken and Shan Cheng from Heriot Watt University (HWU) in Edinburgh arrived back in Cape Town on 27 November, and we again raced straight to SALT to resume the laser comb integration that had started in August. Many more parts had either been delivered, modified or completed in the time since, and the two of them eagerly fell upon the components in their quest to get the various systems going.

The main titanium sapphire laser again needed some remote attention from the vendor in the UK, but all the other elements performed well. A software interface was quickly set up for the new frequency counter, and the new mounting blocks manufactured in the SAAO workshop greatly simplified the alignment of the photonic crystal fibre. A gorgeous, and remarkably powerful(!) super-continuum (a brilliant array of individual laser spots that blur into a red-through-greenish spectrum) was promptly generated — a big relief after the difficulties experienced back in August.

Working at least 14-hour days, there were some ups and downs along the way, but overall progress was being made at a good pace. Derryck Reid (also from HWU) and our UK-based pipeline developer for the high-stability mode of the HRS, Daniel Holdsworth, joined us at the telescope most of a week later. The rest of the trip was a blur of optical alignments, tinkering with electronic locking loops and hacking of various software interfaces to get all the equipment controllable from the comb laptop.





Unfortunately, a firmware update to the laser went awry on the Tuesday and led to both the vendor and the local team no longer being able to access or control the laser — at all. At the time of writing, we are still awaiting a recovery process, that will likely take the form of a dongle that can physically be plugged in to the laser controller. This was a major blow given all that was planned for the remaining days, though the team still made productive use of their remaining time on site.

Richard (and Shan) will most likely return to SALT in mid-February to pick up where they left off, and there is of course other work to do in the meantime. This includes running more HRS stability tests to characterise the instrument performance (as Daniel's code can now deal with simultaneous thorium-argon data for both the Blue and Red channels of the HRS), as well as putting more software tools together to interface with the various devices and sub-systems associated with the comb.

The team spent the Thursday tidying everything up in the HRS electronics room where the LFC optical bench is located, before heading down to the dam in the afternoon to join the Tech-Ops year-end braai. Our northern friends thoroughly enjoyed the occasion, particularly the expertly cooked boerewors and lamb chops! We then set off early on Friday morning (8 December) in pursuit of the Veldskoen farmstall's amazing buttermilk flapjacks on our way back to Cape Town. Everyone made it to the airport in good time, though sadly one of the bottles of hot sauce bought along the way failed to survive the trip to Scotland, so Richard will be needing a new suitcase for next time!

Lisa Crause.--

SALT SCIENCE PAPERS

August 2023 – November 2023

Below is the list of SALT publications since our last newsletter (for our full list of publications, please visit http://astronomers.salt.ac.za/data/publications/). We encourage SALT users to inform us of any papers making use of SALT data, and to double check the link above after publication.

- O'Connor, B., Göğüş, E., Hare, J., et al. 11/2023: Swift Deep Galactic Plane Survey classification of Swift J170800-402551.8 as a candidate intermediate polar cataclysmic variable, MNRAS 525, 5015 -- https://ui.adsabs.harvard.edu/abs/2023MNRAS.525.5015O
- Snowdon, E. J., Jeffery, C. S., Schlagenhauf, S., Dorsch, M., & Monageng, I. M. 10/2023: Ton S 415: a close binary containing an intermediate helium subdwarf discovered with SALT and TESS, MNRAS 525, 183 -- https://ui.adsabs.harvard.edu/abs/2023MNRAS.525..183S
- Imbrogno, M., Israel, G. L., Rodríguez Castillo, G. A., et al. 10/2023: Discovery of a magnetar candidate X-ray pulsar in the Large Magellanic Cloud, MNRAS 524, 5566 -- https://ui.adsabs.harvard.edu/abs/2023MNRAS.524.5566I
- Prince, R., Zajaček, M., Panda, S., et al. 10/2023: Wavelength-resolved reverberation mapping of intermediate-redshift quasars HE 0413-4031 and HE 0435-4312: Dissecting Mg II, optical Fe II, and UV Fe II emission regions, A&A 678, A189 -- https://ui.adsabs.harvard.edu/abs/2023A&A...678A.189P
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