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STATUS OF SALT, AND JOINT SCIENCE PROJECTS WITH GTC

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RESUMEN

El Gran Telescopio de Sudáfrica (SALT) inició su primer período de operación científica a finales de 2011, dando resultados que demostraban el potencial del paradigma del espejo esférico, bajo costo y gran telescopio. Esto solo fué posible tras resolver dos problemas técnicos que retrasaron el proyecto varios años. Sin embargo, durante las pruebas y verificación científica fue posible llevar a cabo ciencia variada. Ahora tenemos la posibilidad de colaborar con el GTC, en particular en el área de agujeros negros galácticos transitorios.

ABSTRACT

In late 2011, the Southern African Large Telescope (SALT) entered its first period of normal science operations, and delivered results finally demonstrating the potential of the spherical mirror paradigm for a low-cost, but very large telescope design. This was only achieved after overcoming two serious technical problems, which delayed the project for several years. However, during testing and commissioning it was still possible to undertake some science in a number of areas. There is now the prospect of a very effective collaboration with GTC, particularly in the area of galactic black-hole X-ray transients.

Key Words: instrumentation: spectrographs — methods: observational — telescopes

1. QUICK HISTORY OF SALT

Begun in the late 1990s by a global consortium led by SAAO in South Africa, SALT is a southern counterpart to the McDonald Observatory's 10 m Hobby-Eberly Telescope (HET) in Texas. While the construction was completed by 2005 (for only ∼$20M), and inaugurated by (then President) Thabo Mbeki in Nov 2005, SALT then entered a period of testing and commissioning. The low cost for such a large aperture (a factor 4 or 5 below that of most other 8-10 m class telescopes) was achieved through its spherical primary mirror design. Consisting of 91 1 m-segments which are maintained at a fixed elevation angle of 53° (chosen to bring all of both Magellanic Clouds within SALT's purview), such a geometry allows access to 70% of the sky. For full details see Buckley et al. (2006).

The spherical primary requires a spherical aberration corrector (SAC, located near the prime focus), and this 4-element design feeds corrected light into the instrument payload. The light can be directed into either SALTICAM (an imaging camera, O'Donoghue et al. 2003) or the Robert Stobie Spectrograph (RSS, Buckley et al. 2008), the medium spectral resolution workhorse instrument, which has several modes of operation, including long-slit, multi-slit and Fabry-Pérot spectroscopy. Eventually a fibre feed will also be available once the construction of the High Resolution Spectrograph (to be mounted under the telescope floor) is completed (Bramall et al. 2010).

Unusually, this design means that, during an observation of a given field, the primary mirror is stationary, and the instrument suite is moved on a Tracker across SALT's field of view. This limits the individual observations to an hour or so (up to 3 hours at extreme declinations). This means that observations must be combined over multiple tracks, but it does make long-term (daily or weekly) monitoring of variable objects easy to schedule.

SALT began as a straightforward copy of HET, but early in the project it became clear (from experience with HET) that some major design changes should be made. The most important of these was in the SAC, with SALT's version (O'Donoghue 2000) giving a >4 times larger field of view together with substantially improved optical imaging performance. It also allowed for the provision of a much larger instrumentation package on the Tracker.

1.1. *Technical Problems*

Early in commissioning it was apparent that SALT was suffering from two serious problems. Firstly, the RSS throughput was significantly below specification, particularly in the blue/UV region. Consequently, at the end of 2006, RSS was removed from the telescope and its optics returned to the US

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for assessment and repair. Fortunately, the problem was identified as arising in the lens-coupling fluid used in the collimator/camera lens multiplets, and was the result of an uncatalogued chemical reaction between the fluid and its polyurethane expansion bladder. This was relatively straightforward to correct, and RSS is now reassembled and working close to its original specification (Buckley et al. 2008).

Secondly, and far more importantly, the image quality (IQ) of SALT was found to display a severe focus gradient across its field of view, together with other time-dependent aberrations which prevented useage of anything more than a small fraction of its planned capability. This led Darragh O'Donoghue and his IQ team to undertake a major investigation of this problem. They were able to rule out the instruments themselves as well as the primary mirror array. This left only the SAC, and it was shown that the very simple mechanical mounting of the SAC onto the Tracker, together with its relatively flimsy structure, allowed for mechanical and thermal distortion of its components. Hence a complete redesign of this mechanical interface was undertaken, and this led to the SAC being removed from SALT from April 2009 to August 2010 for these repairs, modifications and realignment to be implemented.

On remounting the SAC onto SALT, the first on-sky images immediately revealed that the IQ problem was solved (Figure 1), and that outstanding imaging could be undertaken with a spherical primary mirror. For full details, see O'Donoghue et al. (2010). It is worth noting that HET is itself constructing at the present time a very wide field multi-spectrograph instrument (HETDEX), and this incorporates a new SAC based on the SALT design (Hill et al. 2008).

2. FIRST SCIENCE RESULTS

SALT's instruments are designed with capabilities that match the science focus areas of the SALT collaboration. These naturally include survey studies that exploit SALT's field of view, and multi-wavelength programs to complement South Africa's expansion into radio astronomy (MeerKAT, and hopefully the SKA) and ultra-high energy γ-ray astronomy (through HESS in Namibia). But they also exploit South Africa's well-established reputation in fast photometry of variable stars and polarisation studies of magnetic interacting binaries. Consequently, the SALTICAM and RSS detectors all have the capability to undertake high time resolution observations (down to approx 20 Hz), and RSS has both a spectroscopic and imaging polarimetry facility.

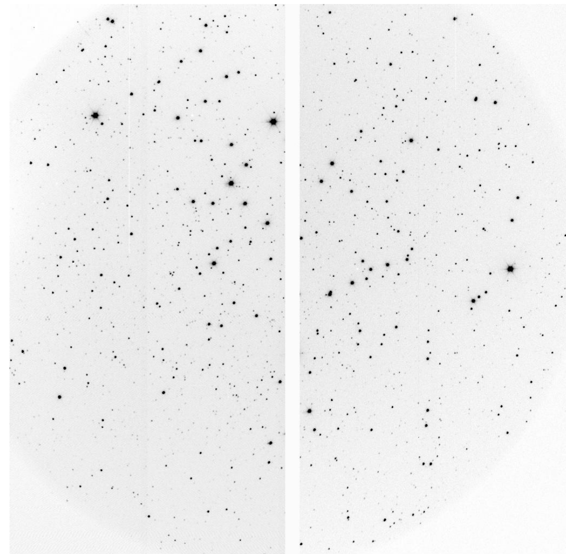

Fig. 1. Full-field (8 arcmin) SALT image obtained in August 2010 following the repair and remounting of the SAC. This image is in sharp focus, with an average FWHM across the field of 0.9 arcsecs.

This high speed capability featured in SALT's first science paper (O'Donoghue et al. 2006) using data obtained during the initial commissioning year. The eclipses of the white dwarf in the magnetic CV, SDSS015543+002807) were fully resolved (even though they lasted only a second or so), showing *two* steps in both ingress and egress. This revealed that both magnetic caps on the white dwarf were visible and their physical location and size measured. To achieve such a result required combining high time resolution with large telescope aperture.

But the most important recent results have come after the SAC repair in that they demonstrate how well both of SALT's technical problems have been resolved. Following the completion of initial imaging tests with the repaired SAC, RSS was remounted on SALT in April 2011, just as the recurrent nova T Pyx was undergoing its first nova outburst since 1966! This provided an excellent opportunity to exercise many of the RSS modes of operation, including spectropolarimetry. In particular, the (very) blue spectrum of accreting binaries provided an excellent test of RSS' blue sensitivity, and a spectrum was obtained of T Pyx (Figure 2) that extended to the atmospheric cutoff near 320 nm.

3. FUTURE SCIENCE WITH SALT AND GTC

With SALT operations being entirely Q-scheduled (a necessary consequence of its restricted sky access, with only ∼1/6 of the sky accessible at

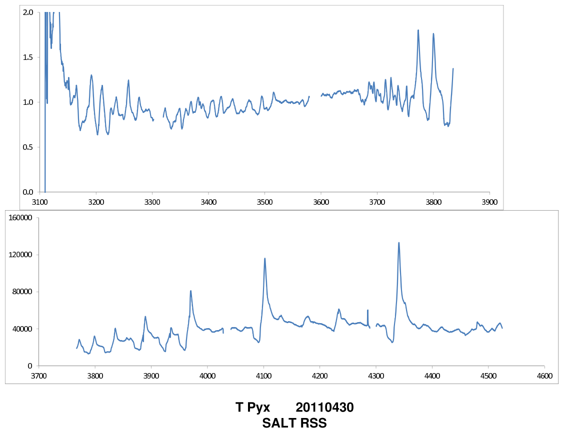

Fig. 2. SALT/RSS spectrum of the recurrent nova T Pyx taken during its 2011 outburst. This shows significant emission down to the atmospheric cutoff, thereby demonstrating the excellent UV/blue performance of the spectrograph following the repair of its optics.

any given time), and with GTC being largely Q-scheduled, this opens up the potential to undertake science that would be extremely difficult to perform in classical observing modes (see e.g. Charles 2010). In particular, this makes it possible for ToO (Target of Opportunity) programs to follow up transient phenomena at very short notice. SALT has even managed to already obtain spectra of a GRB afterglow a few hours after the event (thereby confirming the redshift of the event, Still et al. 2006). With the growth of robotic monitoring and survey facilities around the globe (e.g. SuperWASP, Palomar Transient Factory, PanSTARRS are already operating, LCOGT is under construction, and LSST will be operating by the end of the decade) the study of transient phenomena is now rapidly expanding.

One such field that has developed over the last two decades, much of it based on observations from La Palma and Tenerife, is that of studying the soft X-ray transients. As already mentioned at this workshop (Corral-Santana et al. 2012), these X-ray transients have proven to be an outstanding hunting ground for stellar-mass black holes within our Galaxy, and they have made it possible to accurately determine their binary parameters. In particular, we now have ∼20 black-hole masses determined in ways that depend only on application of Kepler's laws (see e.g. Charles & Coe 2006). One limitation on this method is that many of these transients are too faint in quiescence for detailed spectroscopy of the mass donor, even with 10m telescopes. However, a method has been pioneered by Steeghs & Casares (2002) to exploit the X-ray irradiation of the inner face of the donor which can produce fluorescence features and thereby a radial velocity curve of the secondary, even during X-ray outburst (when the optical emission is dominated by that from the accretion disc). This has already been applied to a number of the so-called "steady" luminous galactic X-ray binaries (see Cornelisse et al. 2008), but it can also be applied through ToO programs to X-ray transients in outburst. Such a program is already in place at SALT, and could be combined with GTC to enhance the coverage of such transients during their outburst phase, thereby greatly increasing the number of accurate compact object mass determinations in our Galaxy, a result of great interest for high mass stellar population and evolution studies.

There are countless other potential areas for joint science between SALT and GTC, such as ultra-compact binaries, ultra-luminous X-ray sources in nearby galaxies and superorbital variations in Be X-ray binaries, all of which are planned for SALT. All of these represent merely the start of opening up the new frontier of "Time Domain Astronomy".

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