Call for Expressions of Interest from SALT users for Science Verification observations with the High Resolution Spectrograph (HRS) in 2012

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08 Dec 2011

Introduction

At the November 2011 SALT Board meeting it was mentioned that a draft "Expressions of Interest" document for the science verification phase of SALT HRS had been drafted. An action on DB was to distribute the final version of the document at the earliest opportunity.

SALT HRS will deliver stable, high-resolution (R = 16000, 37000 and 65,000) spectra over a wide wavelength band ($\Delta\lambda \sim 500$ nm) for a single object and a sky sample. It is principally suited to science that requires essentially complete optical spectra at high resolution, of targets with a low density on the sky. These are the targets for which multiplexed spectrographs on other telescopes offer no competitive advantage, and for which the large aperture, high stability and wide wavelength coverage of SALT HRS offer distinct advantage.

With HRS at a stage where it will be shipped to SALT in mid-2012, it is critical that projects for the Science Verification phase in the second half of 2012 are considered and developed as soon as possible. We are therefore proposing that the SALT community submit HRS commissioning proposals by the end of May 2012.

This paper summarises the key features of SALT HRS and some of the science that was proposed by the community a decade ago. This paper is also a call for Expressions of Interest in Science Verification observations. It gives users an opportunity to reflect on this in order to propose new and exciting science that will demonstrate the versatility of this telescope / spectrograph combination.

Science Drivers

The SALT HRS science case was developed through community consultation (see Appendix) when the instrument was undergoing early design phases. A number of scientific applications were identified which informed later design stages. Four (non-exhaustive) examples of science are described below.

Stellar radial velocity measurements
Radial velocity measurements vary greatly in the accuracy that they require. SALT HRS will provide data for kinematic and dynamical studies of faint stellar populations in the Galaxy and some Local Group targets, as well as precision radial velocities using either an iodine cell, simultaneous Th-Ar arc injection or fibre double scrambler (or suitable combinations of these).

SALT HRS will be installed in a vacuum tank to avoid variations in the refractive index of air with pressure or temperature that is one of the major limitations on accuracy at the sub-km s^{-1} level. The fibre-fed HARPS regularly attains ~1 m s^{-1} accuracy (at R = 115,000) without an iodine cell; at R = 65000, SALT HRS will use the previously mentioned precision techniques (iodine cell; Th-Ar arc; scrambler) to achieve comparable precision. These modes will be well suited to the study of extra-solar planets.

Stellar atmosphere analysis
Stellar atmosphere analyses cover a wide range of astrophysical sites, for example the photospheres, chromospheres and coronae of late-type active stars, pulsating stars, stars with winds, and interacting binaries. Such studies often require data at high resolution of widely-separated spectral features, which is precisely the capability of SALT HRS. Simultaneity at widely separated wavelengths is not only more efficient of observing time but can be crucial in the case of variable phenomena related to outbursts or orbital phase. Doppler tomography and eclipse mapping are two examples of the unique outputs achievable from observations of this nature. Many programs will also benefit from synoptic observations taken on timescales of days-weeks-months-years.

Chemical compositions of stars
Abundance studies generally benefit more from high spectral resolution than from high S/N in the continuum. For this reason, high spectral resolution is usually advantageous, and this reflects the drive for R up to ~ 65,000. Moreover, the highest resolving powers are essential for dealing with blended spectral features. Chemical composition studies of the stellar populations and chemical evolution of the Galaxy and nearby Local Group members are likely to be key targets for SALT HRS. The Galactic population studies RAVE and Gaia are based around the Ca IR triplet at 848-868 nm. SALT HRS will cover this region.

Interstellar and intergalactic absorption
SALT HRS will be installed on one of the largest telescopes in the southern hemisphere, capable of simultaneously recording widely separated absorption lines and diffuse interstellar bands at moderate resolving power (R ~ 65,000), and hence should make an important contribution to the study of Galactic, Local Group (including Magellanic Clouds) and high-redshift absorbers, particularly for faint sources which have been out of the reach of more modest telescopes.

Description of Operational Modes

Low-Resolution Mode (with Nod and Shuffle)
The lowest resolving-power, R = 16000 configuration should be seen as a specialist mode. This configuration offers the same fibre input diameter as the R = 37000 mode but with two beneficial differences: nominally 1.4× higher throughput because the fibre output is not image-sliced (hence the coarser resolution), and the opportunity to use nod-and shuffle for improved sky subtraction. The nod-and-shuffle operation samples two different sky fields on either side of the target, for half of the total exposure time in each case. It ensures that object and sky spectra can be extracted from the same pixels on the CCD. In addition, the starlight falls on two different regions of the CCD (corresponding to the two fibre positions) and hence benefits from a SQRT(2) reduction in the impact of residual flat-field noise, but without an increase in read-noise.

This improvement in sky sampling and reduction in flat-field residuals will benefit observations of the faintest targets requiring the lowest resolving power. Examples where the lowest resolving power may be tolerable and where the improved background sampling might be beneficial include spectroscopy of diffuse interstellar bands against lines of sight to distant stars or quasars, and molecular band analyses of stars in Local Group galaxies.

Medium Resolution Mode
The R = 37000 mode is expected to be the most commonly used SALT HRS mode. It has adequately high resolving power for many projects but with a larger fibre diameter and larger

throughput than the $R = 65000$ mode. Studies of objects whose intrinsic line widths are broader than two resolution elements of the $R = 65000$ mode, such as rotating stars (e.g. most O and B stars), stars in which the Balmer line strength measurements are the principal aims, and studies of molecular bands at medium resolution are likely to benefit from the resolving power vs throughput trade-off available in this mode.

High Resolution Mode

The $R = 65000$ mode is likely to be selected only by those projects for which the lower throughput compared to the $R = 37000$ mode is more than offset by the greater resolving power. One such category of observations will be studies of line profiles in investigations of stellar atmosphere dynamics, the measurement of isotope ratios, or the study of absorbing structures in the interstellar or intergalactic medium at the highest velocity resolution. This resolving power will also be preferred for spectral work in crowded spectral regions, such as in efforts to detect the weak, partially blended lines of key elements in abundance analyses. Studies that benefit from fine sampling of the stellar line profiles, such as the most precise radial velocity work, will also utilise this resolving power. Recall, however, that the wavelength stability of the instrument as a whole will be much higher than in traditional non-vacuum spectrographs, and astronomers may find they can achieve adequate velocity accuracy even at $R = 37000$ because of the improved systematics compared to other spectrographs.

Precision Radial Velocity Mode

The precision radial velocity mode will be implemented at $R = 65000$, because of the importance of adequately sampling the line profiles in order to achieve sub-resolution element accuracy. (An error of 0.5 m s^{-1} corresponds to 10^{-4} of a resolution element!). The light path includes a ‘double scrambler’ to improve the radial scrambling of the fibres and reduce the spectral shifts due to the star moving on the input face of the fibre. In this mode it is also possible to place an iodine cell in the beam (both channels) to provide a superimposed set of wavelength reference lines in the 500-620 nm range, or to illuminate the second (sky) fibre with an internal Th-Ar calibration source to obtain a simultaneous wavelength calibration. The efficiency of this mode is therefore expected to be ~50%-70% of the normal high resolution mode and would normally only be used where this level of wavelength stability is essential.

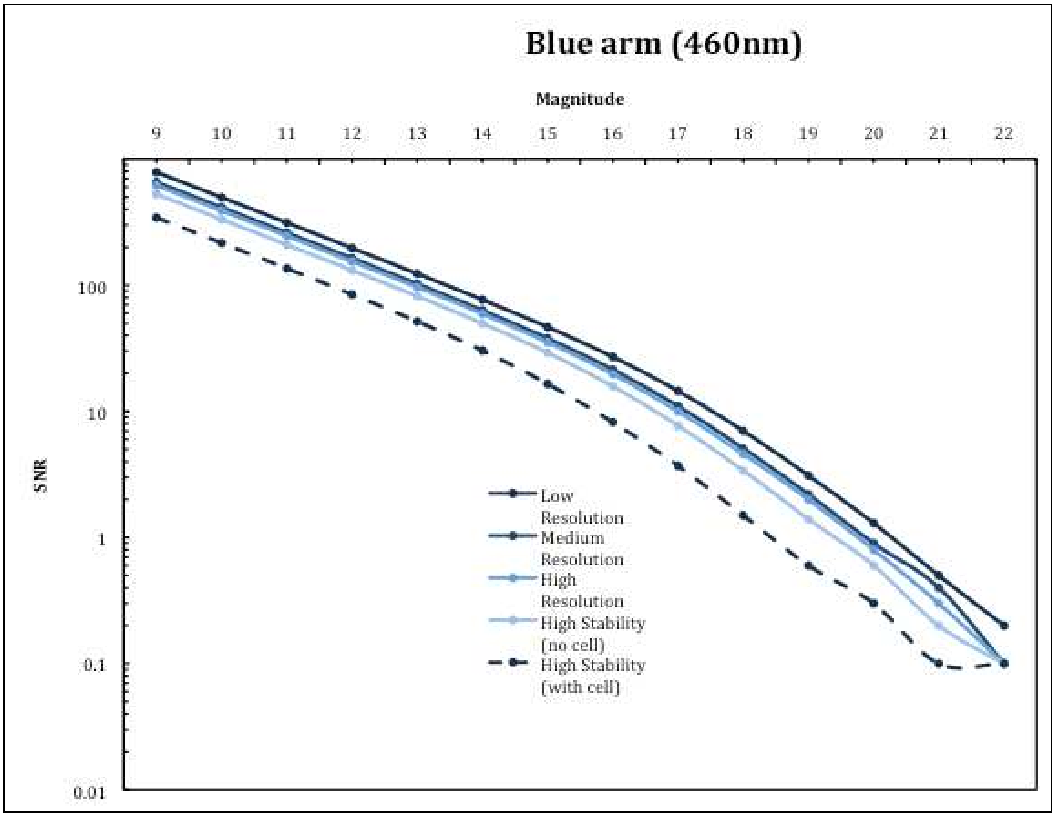
Calibration

Wavelength calibration for the first three modes will be undertaken using the SALT Calibration System and consist of a set of Th-Ar hollow-cathode lamp spectra obtained through both fibres. These calibrations will normally be taken during the day. Spectrophotometric standard stars will normally be observed during twilight (at no cost), although they can be requested (as indeed can other standards or calibrators) at other times during the night, which will be charged for.

Table 1. Summary characteristics and efficiency predictions

	Resolving power		
	Low	**Medium**	**High**
Fiber diameter (arcsecs)	2.23	2.23	1.56
Slit width (arcsecs)	1.673	0.710	0.355
# of slices	1	3	3
Blue arm	16200	36600	64400
Red arm	16200	37300	69200
Blue arm transmissions [spc+slt+tel] (%)[1]	13.4	9.4	6.0
Red arm transmissions [spc+slt+tel] (%)[1]	17.4	12.1	7.7

[1] At the blaze wavelength of each order



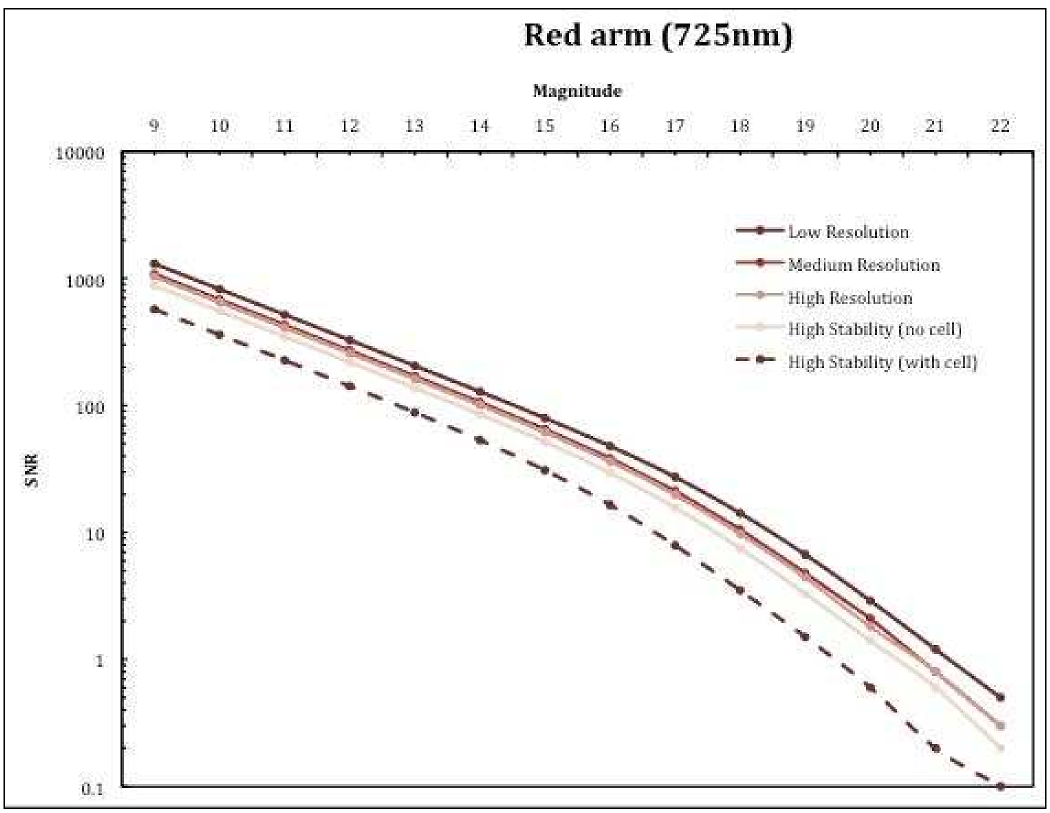


Figure 1. The expected signal to noise ratio (S/N) of SALT HRS as a function of stellar visual magnitude (m_v) and exposure time. The calculations are for wavelengths of 460 (blue arm) and 725 nm (red arm) and the low (R~16,000), medium (R~35,000) and high (R~65,000) spectral resolving powers. A G dwarf star, 1 arcsec seeing, exposure time of 1800 sec and a telescope airmass of 1.3 are assumed. The sky brightness is calculated assuming the moon to be at first quarter. The S/N is for each extracted half-resolution element at the echelle blaze peak.

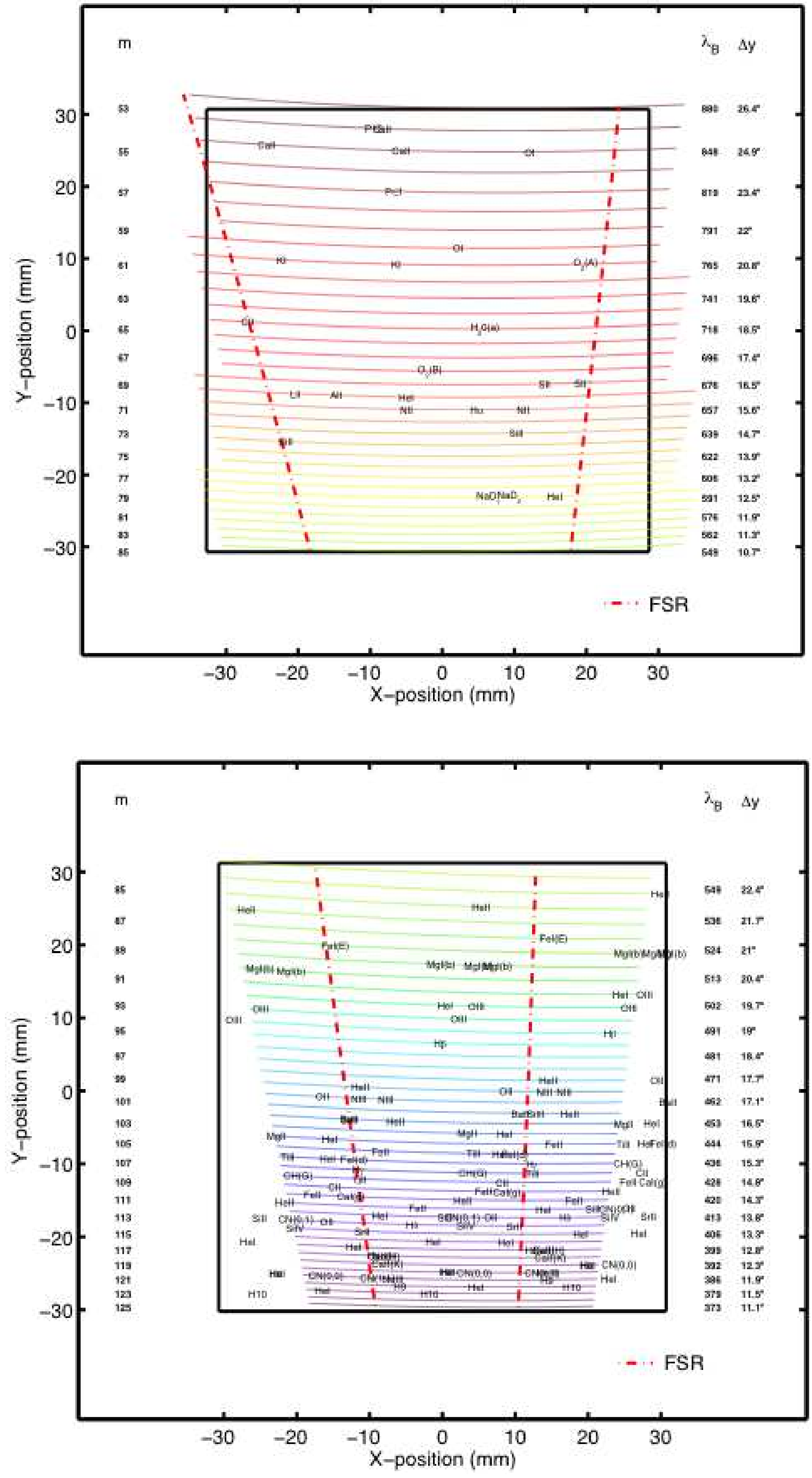


Figure 2. Wavelength coverage for the red (top) and blue (bottom) arm of SALT HRS. Key spectral features are noted on each image.

Call for Expressions of Interest

Current expectations are that HRS will have two instrument commissioning periods starting in August 2012, followed by a science verification phase in November 2012. In practice, some science verifications observations may be made in the earlier session, and some commissioning may take place in the second session.

SALT is pleased to make this call for expressions of interest from members of the SALT user community for observations to be made during the science verification phase. Expressions of interest should be submitted using the SALT Phase 1 proposal tool by 31 May 2012. This will be the same procedure as for the existing instruments, SALTICAM and RSS (see: www.salt.ac.za/observing/proposing-for-salt-observations/phase-i-proposal-instructions/.)

This tool will be updated by 1 May to allow the required HRS parameters to be entered. The expression of interest should contain the following information, some of which will be entered into the Phase 1 proposal form, and some in the supporting text file (scientific & technical justification, immediate objectives):

- name of proposers, email addresses, and their institutions
- resolving power required and whether special modes are required (e.g. nod and shuffle at R = 16k; iodine cell; simultaneous ThAr; double scrambler)
- targets, which must be available in the latter part of 2012/early 2013
- observation times, not exceeding 10 hrs in total for the proposal (inclusive of overheads)
- calibration requirements (especially any non-standard calibrations)
- scientific and technical case for the observations and a statement of why these observations would be a good test or demonstrator of HRS capabilities (in Sections 11-13 of the proposal form)
- confirmation that the proposers reasonably expect to have the resources and the time in the latter part of 2012 to conduct the scientific analysis of any science verification observations and feedback to SALT and the HRS development team on the outcome of the observations within four weeks of receiving the data. Data taken during the Science Verification phase will be made available for use of SALT and by the HRS development team for the purposes of examining or reporting the performance of the instrument.
- The Science Verification phase will be limited to the extent necessary to prove the performance of the instrument, with an expectation of allocating 100 – 150 hours during 2012 Semester 2 (1 Nov 2012 – 30 Apr 2013).
- Programs accepted for Science Verification will not be charged for, as in previous commissioning calls.

Expressions of interest will be assessed by a panel established by the SALT Science Director specifically for the HRS science verification phase, having regard to the suitability for the projects for testing, proving and demonstrating the capabilities of HRS, and to their greater scientific merit. The panel will consist of the HRS Principal Investigator and Science Advisor and other members of the HRS commissioning and operations teams.

References

Design specifications for HRS are published in:

Barnes et al 2008, Proc of SPIE 7014, 70140K

Bramall et al 2010, Proc of SPIE 7735, 77354F.

Appendix:

Science goals for SALT HRS (circa 2000)

_ Element abundance measurements, especially in extremely metal-deficient stars.
_ Stellar populations and dynamics of intermediate redshift galaxies.
_ Chromospheric modeling of early-mid M dwarfs.
_ Spectra of very late M and early L dwarfs for modeling with PHOENIX.
_ High Balmer line spectra of late-type M flare stars.
_ Stellar spectroscopy in globular clusters.
_ Stellar spectroscopy in local group galaxies.
_ Time-resolved spectroscopic monitoring of flares on late-type stars.
_ Rotational velocities of members of galactic clusters.
_ Follow-up studies of faint objects in COROT fields.
_ Extrasolar planet detection.
_ Asteroseismology.
_ Abundance studies in Magellanic Clouds.
_ RV studies in visual binaries.
_ Line profile studies of pulsating stars.
_ Doppler imaging of spotted stars.
_ To resolve Herbig-Haro Objects and flows near protostars.
_ Internal dynamics of star clusters and dwarf galaxies.
_ Element abundances for stars in the Galactic disk, bulge and halo, as well as stars in globular clusters and dwarf galaxies.
_ Abundances and distance measurements for stars and QSO's in the direction of dwarf galaxies and high-velocity clouds.
_ Abundance analyses of main-sequence, red giant branch and asymptotic giant branch stars in the field and in clusters.
_ Line profile work in moving atmospheres.
_ Studies of highly peculiar stars.
_ Ultrahigh resolution spectroscopy of ISM - fine structure of diffuse bands, low abundance molecules etc.
_ Ultrahigh resolution spectroscopy of emission nebulae, CS shells.
_ Ultrahigh resolution spectroscopy of carbon stars, outflows etc.
_ Diffuse band carriers in the Magellanic Clouds.
_ Extrasolar planet detection and spectroscopy.
_ Spectroscopy of elliptical galaxies at moderate redshifts ($z = 1$-2).
_ Spectroscopy of ultra high-redshift galaxies.
_ Redshift identification of DLA absorption at $z < 2$.
_ Acquisition of large numbers of high precision radial velocity measures of cluster stars.
_ Determination of distances to selected galactic and globular star clusters.
_ Determination of amount of absorption in the ISM along the line of sight to the clusters.
_ Study of Galactic structure and stellar dynamics and stellar and Galactic evolution.
_ Testing theoretical models for post-AGB evolution and discovering the evolutionary origin of extreme helium stars.
_ Internal structure, physical dimensions and atmospheric activity in pulsating stellar remnants.
_ Physical dimensions and stellar outflows from type IB supernovae progenitors.
_ Abundance and pulsation studies of stellar remnants in globular clusters and other galaxies.
_ Time-series spectroscopy of pulsating white dwarfs.
_ Abundance analysis/high-precision time-series spectroscopy of pulsating A-type stars.
_ Line profile variation studies of pulsations in roAp stars.
_ Time resolved studies of emission lines in accretion disks.
_ Studies of chromospheres of active stars.
_ Jets and stellar outflows.
_ Spectroscopy of cool secondaries in CVs.
_ Monitoring of variable absorptions beta-Pictoris like stars.
_ Velocity curves of eclipsing binary stars in the Magellanic Clouds.
_ Doppler imaging of the secondary stars in cataclysmic variable stars.
_ Radial velocity searches for double degenerate binary stars.
_ Spectra of luminous, compact stellar systems--super star clusters (such as NGC 1705).

_ Studies of novae, symbiotic stars and related classes.
_ Moderate precision (sigma < 1km/s) stellar radial velocities to V = 20 and I = 22 in high-stellar-density environments.
_ Moderate resolution study of accretion diagnostics in high-stellar-density environments, with an emphasis on time variability of accretion line profiles.
_ Stellar Zeeman Effect.
_ Stellar, circumstellar, and AGN Linear spectropolarimetric profiles.
_ Heavy element evolution over 10 Gyr of cosmic time via QSO absorption line observations of matter in the IGM.
_ Radial velocity searches for binary central stars of planetary nebulae (including sub-stellar companions).
_ Abundance studies of cool central stars of planetary nebulae (especially Barium stars).
_ High quality spectroscopy of central stars of planetary nebulae (e.g. NLTE modelling of Wolf-Rayet central stars)