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High-resolution near-IR spectroscopy: from 4m to ELT class telescopes

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1. Introduction

High-resolution (HR) near-IR spectroscopy is opening new windows in our understanding of several hot topics of modern planet, stellar and extragalactic astrophysics, and it will have a huge impact in the JWST and ALMA era and beyond. The much reduced extinction at these wavelengths allows to pierce the dust embedding those objects which are heavily obscured in the optical. Moreover, at high redshifts several spectral features, commonly exploited when studying local galaxies, are shifted into the near-IR. However, despite its scientific potential, the field of HR IR spectroscopy and its related science is developing very slowly, because of the lack of optimized instruments with the necessary combination of spectral resolution and coverage.

High spectral resolution (R$\sim$100,000) is crucial to properly resolve the spectral features and derive accurate chemical and kinematic information of individual stars, stellar clusters and galaxies. A wide spectral coverage in a single exposure is highly desirable for a complete screening of chemical abundances in stellar populations or for extremely accurate radial velocity measurements for extra-solar planet search, which also require high stability. A wide spectral coverage is also crucial to unveil the nature and physical properties of poorly explored objects, like e.g. very low mass dwarfs or transient objects.

2. Scientific highlights

The inner Galaxy, where dust obscuration makes optical observations virtually impossible, is the most suitable laboratory to study stellar physics, kinematics, evolution and chemical enrichment in the high metallicity domain, with a major impact in our understanding of extragalactic bulges and elliptical galaxies. Using existing 4-10m class telescopes one can study the bright, evolved stellar populations of red giants and super-giants, Rich, Origlia & Valenti (2007). However, pristine abundances, which are best recorded in much fainter main sequence stars, can only be accessed with an ELT.

Extragalactic stellar clusters trace the star formation history and evolution of their host galaxies. HR integrated spectroscopy in the near-IR offers a unique chance to characterize the chemical composition and kinematics of these objects even in extincted nuclear and/or star-forming regions (Larsen *et al.* (2008)). With existing telescopes one can measure stellar clusters in the Local Group, while an ELT is mandatory to study old stellar clusters out to Virgo, and young super star clusters out to 50-100 Mpc.

HR near-IR spectroscopy is also a unique tool to constrain the pristine metal and dust formation in low density environments, as traced by Lyα absorption systems at high redshifts (Prochaska *et al.* (2007), Wolfe (2005)).

Other relevant topics in stellar astrophysics, which strongly benefit from HR IR spectroscopy are circumstellar disks, brown dwarfs, stellar magnetic fields and stellar winds. We finally mention that HR near-IR spectroscopy is also a unique tool for the characterization of planet atmospheres in the solar system, (Lellouch *et al.* (2009)), the search for exo-planets (Marcy & Butler (1998)) with habitable conditions and the physics of exo-planet atmospheres (Brown (2001), Swain, Vasishti & Tinetti (2008)).

Moving from 4-8m class telescopes to an ELT, one can pierce objects and/or spatially resolved structures, with 1 to 2 orders of magnitude better limiting sensitivities and/or at $\geqslant$5 times larger spatial resolution and distance.

Table 1. Expected limiting Vega magnitudes of SIMPLE on the E-ELT in 2hr integration.

S/N	$I(0.90\ \mu\text{m})$	$Y(1.05\ \mu\text{m})$	$J(1.25\ \mu\text{m})$	$H(1.65\ \mu\text{m})$	$K(2.20\ \mu\text{m})$
10	20.2	20.7	20.9	21.1	20.6
50	17.6	18.1	18.3	18.6	18.4
100	16.2	16.7	16.9	17.2	17.1

3. A *simple* instrumental concept

We developed an instrument concept for a HR near-IR spectrometer virtually independent on the telescope diameter, following from a detailed study of existing HR optical and IR spectrographs. The current baseline characteristics of the spectrograph are as follows (Oliva & Origlia 2008).

- spectrograph in vacuum cooled and thermostated at cryogenic temperatures
- fixed position at the telescope
- resolving power of at least $R = 100{,}000$ (goal 150,000)
- complete 0.85-2.5 μm spectral coverage in a single exposure
- fixed spectral format, cross-dispersed echellogram

Cross dispersion is performed by means of prisms in double pass mode, which provide a minimum inter-order distance of about 60 pixels. The detector can be a mosaic of three 2048^2 Hawaii-II RG arrays with 18μm pixels or a mosaic of three 4096^2 arrays with 15μm pixels, a format which may soon become the standard for HgCdTe arrays. The sky projected slit width is 0.38", 0.19" and 0.038" on a 4m, 8m, 40m. On the largest telescopes the instrument needs to be assisted by adaptive optics to concentrate the light in the slit. The limiting magnitudes for point sources scale with telescope size as follows

$$m_{lim} = \text{constant} + 5.0\log_{10}(D_{tel}) + 2.5\log_{10}(SLE)$$

where D_{tel} is the telescope diameter and SLE is the fraction of light falling in the slit. A dedicated study of such an instrumental concept for the 42m E-ELT (i.e. the "SIMPLE" study) is underway. The expected limiting magnitudes are summarized in Table 1.

References

Brown, T. M. 2001, *ApJ* 553, 1006

Larsen, S. S., Origlia, L., Brodie, J., & Gallagher, J. S., 2008, *MNRAS* 383, 263

Lellouch, E., Sicardy, B., deBergh, C., Käufl, H., Kassi, S., & Campargue, A., 2009, *A&A* 495, L17

Marcy, G. W. & Butler, R. P. 1998, *ARA&A* 36, 57

Prochaska, J. X., Chen, H.-W., Dessauges-Zavadsky, M., & Bloom, J. S. 2007, *ApJ* 666, 267

Oliva, E. & Origlia, L. 2008, *SPIE* 7014, 560

Rich, R. M., Origlia, L., & Valenti, E. 2007, *ApJ* 665, 119

Swain, M. R., Vasishti, G., & Tinetti, G. 2008, *Nature* 452, 329

Wolfe, A. M., Gawiser, E., & Prochaska, J. X. 2005, *ARA&A*, 43, 861

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