FIRST SCIENTIFIC RESULTS OF THE NEAR INFRARED SPECTROGRAPH LIRIS

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Abstract: LIRIS is a near-infrared (1-2.5 microns) intermediate resolution spectrograph (R=1000-3000) with added capabilities for multi-slit, imaging, coronography, and polarimetry, built by the IAC as a common instrument for the 4.2m WHT (La Palma, Spain). LIRIS has been used as a visiting astronomer instrument at the WHT since summer 2004. The image quality is of 0".5 in the Ks band over the whole field of view (4.2 x 4.2). Very low values of sky brightness have been measured. Currently, R=1000 is available in the three bands (J, H, Ks), whether R=2500 is only available in the Ks band. R=3000 will be available in the J, H and Ks bands, along year 2007. Here we present some scientific results, as the detection of the CIV 154.9 nm line in the most distant qso at z=6.41.

1 Introduction

The advancement of Infrared technology over the past few years, especially in the fields of detectors and cryogenics, has allowed the development of IR spectrographs with similar characteristics to optical ones. LIRIS [2] is conceived as a common user instrument for the WHT to fill a gap in the current instrumentation at the ORM. LIRIS has imaging, long-slit and multi-object spectroscopy observing modes (R=1000-3000). R=700 is available in all bands with a 0".75 slit (3 pixels). R=2250 is only available in the Ks band. R=3000 will be available in the three bands (J, H, and Ks) along year 2007. Coronography, and linear polarimetry are also available. Image capability allow easy target acquisition for spectroscopy. Table 1 lists the main instrument features of LIRIS.

2 General description

The optical system is based on a classical collimator/camera design [2]. The mechanical design is based on a modular concept, integrated by the following

Focal Station	Cassegrain
Wavelength range	0.9 - 2.4 μm
Array format	Rockwell Hawaii 1024x1024 HgCdTe
Detector scale	0.25 arcsec / pixel
Observing modes Multi-object spectroscopy,	Imaging, Long-slit Spectroscopy, coronography and Polarimetry
Imaging FOV	4.2 x 4.2 arcmin
Imaging sensitivity 1h, S/N=3, FWHM=0.5"	K=21.4, H=22.9, J=24.0, z=24.4
Available Slits	Long slit: (0.75, 1, 2.5, 5) arcsec x 4.2 armin Multi-object: 8 multi-slit masks available.
Spectral coverage	R=1000 z & J-bands (0.887 - 1.531 μm) R=1000 H & K-bands (1.388 - 2.419 μm) R=3000 J-band (1.178 to 1.403 μm) R=3000 H-band (1.451 to 1.733 μm) R=3000 K-band (2.005 to 2.371 μm)

Table 1: Instrument features

modules: the slit wheel (aperture wheel), the collimator assembly, the central wheel assembly (formed by two filter wheels, the pupil wheel and the grism wheel), the camera wheel and finally the detector assembly. The instrument works at 80K whether the detector at 70 K.

Figure 1 shows the internal flexures between the focal plane where the slit is placed and the detector, for different telescope elevations and position angles. It can be seen that for 1h exposure the maximum flexures are a small fraction of a pixel, being almost negligible for a position close to the zenith.

3 Performance

The image quality, in the J band, was measured in the globular cluster M 5 where the FWHM over the whole FOV (4.2 x 4.2 arcminutes^2) was 0.5", the maximum deviations being of the order of 0.12". Table 2 shows the zero points, instrument efficiency (optics + filter+ detector), limiting magnitude (measured of 3σ in 1 h with a seeing of 0.7"), and sky brightness for each band. The high efficiency is especially remarkable in all the bands. This is mainly due to the high QE of our detector (80% in the H and Ks bands). As we know that the transmission curve of our filters is 80 %, and our grisms 60 %, we can work out the throughput of

Filter	J	H	Ks
Zero point	25.05	25.35	24.50
Efficiency	0.41	0.62	0.52
Lim. Mag.	23.6	22.4	21.8
Average sky Mag/arsecond^2	15.4	14.2	13.0

Table 2: Zero Points, Efficiency, limiting magnitude (3σ in 1 h for a see ing of 0.7”), and average sky magnitude for LIRIS.

our optical system as being in the order of 80%. The fact that our design is based on lenses does not significantly affect the system's efficiency. Another remarkable point is the low value of the sky brightness in the Ks band, among the lowest values recorded in similar instruments, despite the fact that the WHT is not an IR telescope. This demonstrates that as long as the optical design has a cold stop in the pupil plane, it does not matter whether or not a telescope is IR. For spectroscopy the instrument efficiency (optics + filter+ detector) is about 28 % and 33 % for the ZJ and HK grisms respectively.

4 Scientific results

The study of the spectra of astronomical objects in the Near Infrared (NIR) has enormous scientific potential: by using NIR, the composition of the dust can be established, molecular hydrogen can be studied, and high redshift (z=1) galaxies, whose main emission lines of Active Galatic Nuclei (AGN) (for example, Halpha) lie in the NIR region, can also be observed. Since summer 2004 LIRIS has been used as a common user instrument at the WHT. Currently is one of the most demanded instrument at this telescope, and it has been used both as imager and as spectrograph. Scientific programs carried out covered a wide range of topics, from solar system, galactic astronomy, extragalactic astronomy and cosmology. Here we will list some of the first results.

Figure 2 shows the spectra of the most distant quasar known at the time at z=6.41 with mJ = 18.5. After 70 minutes of integration, the CIV 154.9 nm was clearly detected, thus showing the capability of LIRIS to observe very faint targets.

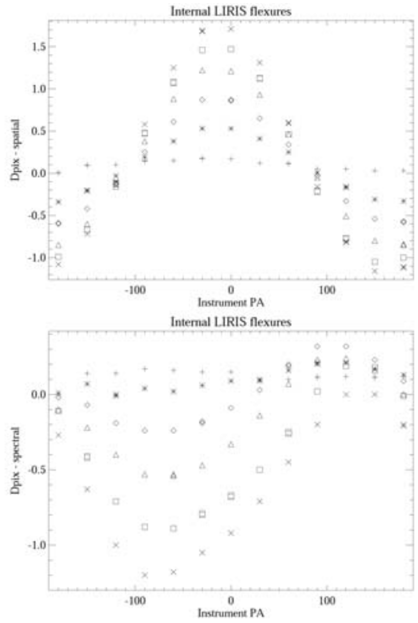

Figure 1: Displacement between the slit plane and the detector both in the spatial and spectral direction for different telescope elevations. Crosses are zenithal distance (ZD) 0, asterisk ZD=15, rhomboid ZD=30, triangle ZD=45, square ZD=60, x ZD=75.

4.1 Brown dwarfs and planet search

Forveille et al. [1] discovered an L0 companion to the nearby M1.5 dwarf G 239-25, at a projected distance of 31 AU. It is the faintest companion discovered so far in a sample of known M dwarfs within 12 pc, and it lies at the stellar/substellar limit. Given the assumed age of the primary star, the companion is likely an extremely low mass star. The long orbital period of G 239-25 AB (100 years) precluded a direct mass determination.

4.2 Supernovae

Mattila et al. [3] obtained infrared images and spectra of SN 2004am on Mar. 6.9 UT, using LIRIS, in the starburst galaxy M82. They detected emission lines of Pγ and Pβ with FWZI of about 2800 km/s. They classified it as a type-II supernova, but highly reddened (with a visual extinction of about 5 magnitudes).

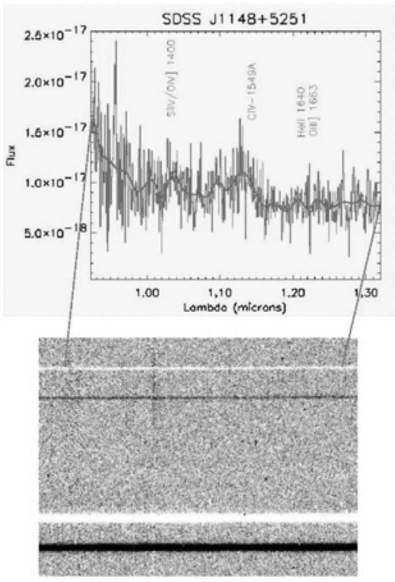

Figure 2: Bi-dimensional spectrum of the most distant QSO, at the time, at z=6.41 in the bottom panel. The extracted spectrum is shown in the upper panel. A fit to the spectrum is also shown, where several broad emission lines are identified. The most intense feature is the CIV line, detected with a S/N ratio of 10. The spectrum is the co-addition of 5 frames of 850 s exposure time each, giving an approximate total time of 70 minutes.

4.3 Active galaxies

Ramos-Almeida et al. [4] obtained NIR spectra of the Seyfert 2 galaxy Mrk 78 with LIRIS. They studied the kinematics and excitation mechanisms occurring in Mrk 78, using the [Fe II], H2, hydrogen recombination lines and the coronal [Si VI]1.962 line. They concluded that despite of the strong radio-jet interaction present in this object, photoionization from the active nucleus dominates the narrow line region emission, while UV fluorescence is the source of the H2 emission

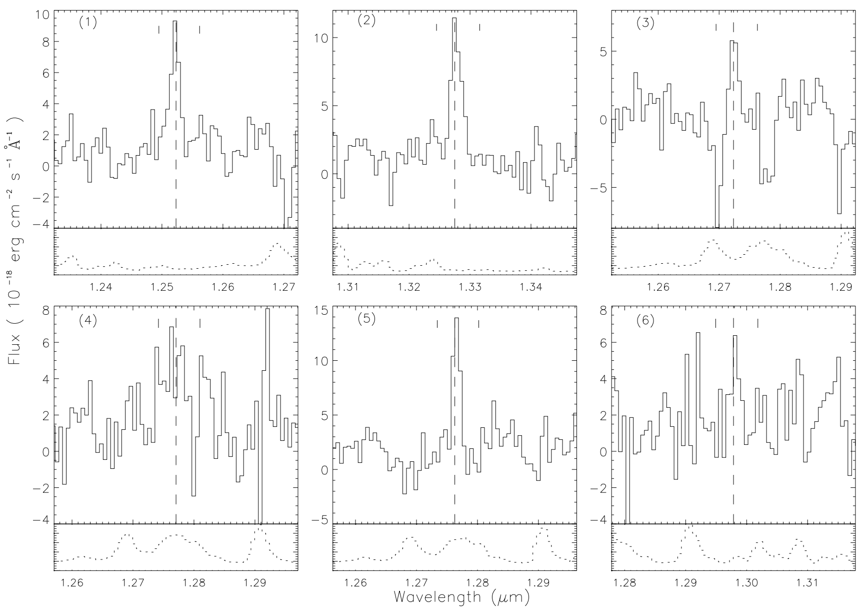

Figure 3: Observed-frame spectra of six z 1 galaxies. The expected position for Hα given the optical spectroscopic redshift is marked with a vertical dashed line, and the vertical bars to either side show the predicted positions of the [N II]λ6548 and [N II]λ6583 lines. Plotted below each galaxy spectrum is the subtracted night sky spectrum in arbitrary flux units. The OH sky lines are not resolved in these spectra.

4.4 Multi-object spectroscopy in the J band of z 1 galaxies

Rodriguez-Eugenio et al. [5] measured the Hα line in five galaxies with redshifts $z \sim 1$. The spectra were obtained with the multi-slit mode (MOS) of LIRIS. From the Hα luminosities the star formation rates (SFR) was derived. This SFR allows direct comparison with the semi-analytic cosmological models. Is this MOS mode which makes LIRIS a very competitive instrument. As an example in Table 2 we show the competitiveness of the MOS mode of LIRIS vs. ISSAC on the VLT.

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Instrument	Exp. time per object	Total exp. time (5 obj)
LIRIS (multi-slit)	—	10800s
ISAAC (long-slit)	2300s	10500s

Table 3: LIRIS competitiveness versus 8-m telescope instruments[1].
Notes: 1) R=3000 spectroscopy in a 4.2 × 1 arcsec field with 5 objects. Given exposure time is for 3σ detection of an emission line at 1.25 μm with a flux of 6 $\times 10^{-17}$ ergs s^{-1} cm^{-2}.

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