TELESCOPES AND INSTRUMENTATION

First Commissioning of the IR Spectrograph LIRIS

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The near-infrared spectrograph LIRIS was first commissioned on the WHT on the nights of 15–19 Feb 2003. During all that time the instrument functioned with no major failures. At the time of commissioning LIRIS included imaging and spectroscopic observing modes. Spectroscopy could be done at low resolution (about 700 using the narrowest slit of 0.65″) using two grisms: One simultaneously covers the bands Z and J (9230–15,425Å) with a dispersion of 6.1Å/pix; and the other covers the bands H and K (14,600–24,946Å) with a dispersion of 10Å/pix.

The weather conditions during the commissioning were good; 3 out of 4 nights were photometric and only half a night was lost due to high humidity. On two of the nights the seeing was about 0.5″, as measured by LIRIS. The image quality over the whole field appeared to be very good (see Figure 2). The PSF over the whole field remained very uniform, with variations of width smaller than half a pixel (0.13″) across the whole field of view. The image quality was very good in the different bands, and the best telescope focus results constant, independent of the filter used.

LIRIS was funded and built by the IAC, the optical and the conceptual mechanical designs were provided under contract by the UKATC. The Spanish contractor INGOVI manufactured the LIRIS vacuum vessel and optical bench. For more detailed information about LIRIS' design, manufacturing and capabilities see Acosta-Pulido et al. (2002, *ING Newsletter*, **6**, 22). For updated information, including instrument simulator, please consult our web site at: `http://www.iac.es/proyect/LIRIS/`.

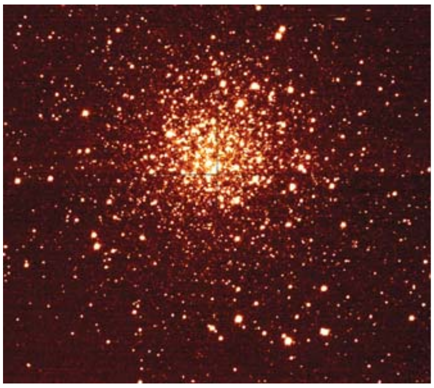


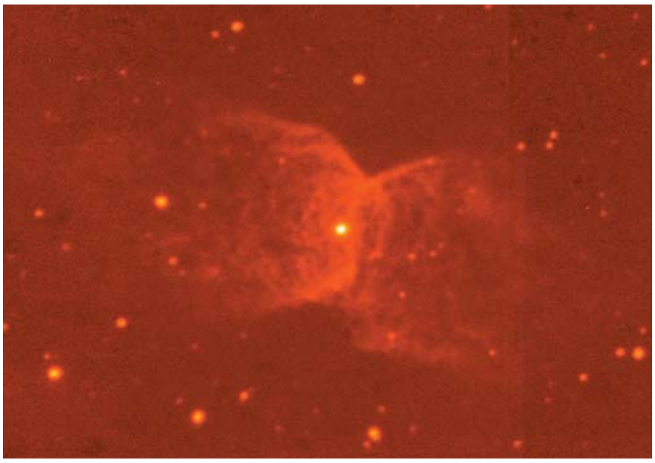
Figure 1 (top left). LIRIS mounted on the WHT Cassegrain focus. LIRIS cryostat can be seen at the bottom of the telescope focus, with the two electronics racks at both sides. Figure 2 (top right). The globular cluster M5 in the J band. The FWHM of the PSF was 2 pixels corresponding to 0.5″. The image quality is very good over the whole field of view (4.2arcmin^2). Figure 3 (right). Arrival of LIRIS at the WHT in January.

LIRIS is equipped with a 1024×1024 Hawaii detector, using a SDSU controller. The engineering detector was used during the commissioning. The detector temperature was kept stable at 61K. The readout noise was 4.8ADU or 24e$^-$ in double correlated mode. This value can be effectively reduced using multiple non-destructive readouts (for instance it reduces to 12e$^-$ when 4 readouts are made). The minimum integration time allowed by the controller is 1s. LIRIS is always limited by background noise for imaging mode in H and K_s bands, and in J band for exposures longer than 4.5s. In spectroscopic mode the same condition is reached for exposure times longer than 380s and 42s in the ranges $Z-J$ and $H-K$, respectively.

The photometric zero point and the system efficiency (optics & detector) were measured in the different bands (see Table 1). We also report the average sky brightness. Remarkably, the sky background in K_s measured with LIRIS is among the lowest reported with similar instrumentation at different telescopes. We would like to point out the fact that the WHT is not an IR optimised telescope. The limiting magnitude was computed for detection at 3σ in an hour of on-source integration with a seeing of 0.7″.

Filter	J	H	K_s
Zero Point	24.83	25.17	24.55
Efficiency	0.34	0.53	0.52
m_{lim}	23.4	22.4	21.8
$<m_{sky}/\text{arcsec}^2>$	15.4	14.2	13.0

Table 1. LIRIS photometric characteristics.



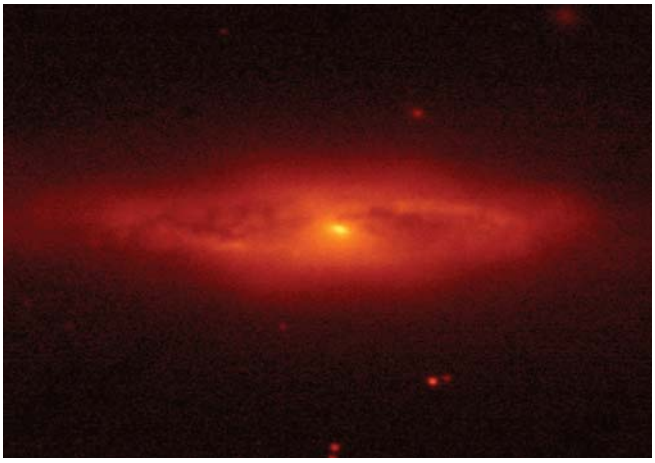


Figure 4 (left). The planetary nebula NGC 2346 in the emission of H_2 $v=1-0$ S(1) at 2.122 μm. The field of view covered in this picture is approximately 3.2 x 2.8 arcmin^2. North is to the right and East is at the top. Note the clumpy structure in the lobes and the bright central star, only visible in the infrared. Figure 5 (right). The Seyfert 2 galaxy NGC 4388 observed in the J filter. The field of view covered in this picture is 2.5x2 arcmin^2. North is at the top and east to the left. Note the very bright active nucleus and the patchy structure of the spiral arms, revealing the presence of obscuring dust lanes.

The rigidity of the instrument, in particular the flexures of the slit wheel with respect to the rest of optics is a critical point for spectroscopic observations. A displacement along the spectral axis during a LIRIS exposure will introduce several unwanted effects, such as smearing of the spectral features, and flux losses due to light coming from the object not passing through the slit. Moreover the position of the slit on the detector needs to be known at any time in order to accurately centre the target object. The LIRIS rigidity was checked with good results. It was found that the maximum shift (with respect to zenith position) along the spectral direction does not exceed 0.5 pixel, or 0.12″, at 45º zenith distance (ZD), although it reaches 0.8 pixel at 60º ZD. The flexures along the spatial direction were slightly worse, reaching about 1 pixel (0.25″) at 45º ZD and certain rotation angles of the Cassegrain turnplate.

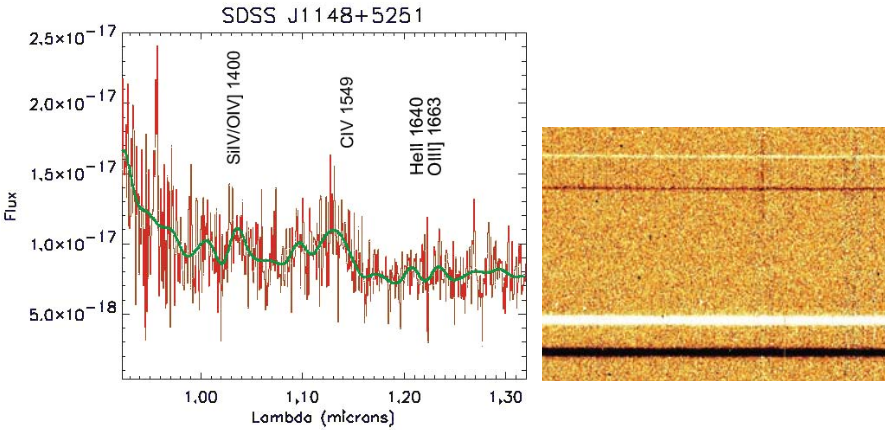


Figure 6. Two-dimensional spectrum of the most distant QSO at $z=6.41$ (top bright row). The extracted spectrum is shown in the left panel. A fit to the spectrum is also shown, where several broad emission lines are identified. The most intense feature is the CIV line, detected with a S/N ratio of 10. The spectrum is the co-addition of 5 frames of 850 s exposure time each, giving an approximate total time of 70 minutes.

A key issue in near-IR astronomy is the sky background subtraction. This is generally performed by following dithering patterns on the sky, which involves a good deal of interaction of the instrument data acquisition with the telescope. The WHT was already prepared for this based on the INGRID experience, although the instrument LIRIS introduces new demands in the spectroscopic mode. For IR spectroscopy the target is often offset along a narrow slit and should be always maintained well centred on it to avoid flux losses. For this purpose the telescope and the auto-guider should work in synchronisation with the instrument data acquisition. It was found that the repeatability of the offsets could not be guaranteed beyond 1 pixel or 0.25″, which involved target re-centring after a couple of movements. However the WHT auto-guider is going to be changed and the situation should improve.

The next commissioning period is foreseen for February 2004. During that period the multi-object spectroscopy mode will be the main focus. We also expect that LIRIS can provide polarimetric and coronographic capabilities.

The instrument has so far been used to observe several astrophysical targets of interest. Some of the initial results are presented in the accompanying figures (see Figures 4, 5 and 6). One of the most remarkable results was the observation of the most distant quasar known at the time (SDSS J1148+5251, $z=6.41$). A spectrum in the bands Z and J was obtained, in which several broad features were detected.

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