

**SPECTROSCOPIC PROPERTIES OF NEW IR GALAXIES DETECTED IN THE EUROPEAN  
LARGE AREA ISO SURVEY**

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ABSTRACT

We present preliminary results of multi-object spectroscopy of new mid-, and far-infrared selected galaxies detected in the European Large Area ISO Survey (ELAIS). The data have been obtained with the fibre spectrographs WYFFOS at the William Herschel Telescope (Observatorio del Roque de los Muchachos, ORM, Canary Islands) and Hydra at the WIYN Telescope (Kitt Peak Observatory, Arizona). The sample includes ISO sources detected at 7, 15 and 90  $\mu\text{m}$  and radio sources from our deep VLA survey in the ELAIS areas.

Key words: Galaxies: formation – Galaxies: evolution – Galaxies: active – Galaxies: distances and redshifts – surveys – infrared radiation

1. INTRODUCTION

The ELAIS project is a collaboration involving 25 European institutes, (Rowan-Robinson, *et al.* 1999, Oliver *et al.* 2000). ELAIS was the largest single Open Time project conducted by ISO, mapping an area of 12 deg<sup>2</sup> at 15  $\mu\text{m}$  with ISOCAM and at 90  $\mu\text{m}$  with ISOPHOT. Secondary surveys in other ISO bands were undertaken by the ELAIS team within the fields of the primary survey, with 6 deg<sup>2</sup> being covered at 6.7  $\mu\text{m}$  and 1 deg<sup>2</sup> at 175  $\mu\text{m}$ .

The ELAIS areas have been also observed at other wavelengths including radio (Ciliegi *et al.* 1999). We have obtained spectra of a sample of sources in the ELAIS regions that includes ISO sources and radio sources from

the deep VLA surveys in these fields. For the spectroscopic follow-up we have used several telescopes and instruments: multi-object fibre spectroscopy with WYFFOS on the WHT at the ORM, HYDRA at WIYN observatory and long-slit spectroscopy at the WHT and NOT at ORM and at the 2.2m telescope at Calar Alto. Here we describe the observations and present preliminary results of the multifibre spectroscopy of the ELAIS fields N1 and N2 (the location of these ISO fields and other related surveys are shown in Pérez-Fournon *et al.*, these proceedings).

2. OBSERVATIONS AND REDUCTIONS

A total of 9 configurations were observed with the WYFFOS spectrograph in May 2000, 3 in the ELAIS region N1 and 6 in N2, as part of the International Time Project to follow-up the ELAIS and Lockman ISO surveys (PI. I, Pérez-Fournon). In average, we observed 68 objects and about 15-20 sky positions for sky subtraction in each pointing. The Hydra data consists of four fibre configurations in the N1 region with about 66 objects and 20 sky fibres per pointing.

Typical integration times of the WYFFOS observations were 90 minutes using two spectral configurations:

- R300B grating, spectral range from 3700 to 9200 Å, and spectral resolution of  $\sim 20$  Å
- R600B and R600R gratings, with about 3000 Å spectral range each, and a combined spectral range similar to the R300B grating but with a better resolution of  $\sim 10$  Å.

The Hydra set-up was the same in all pointings. The spectral range is 4200-9100 Å with a spectral resolution

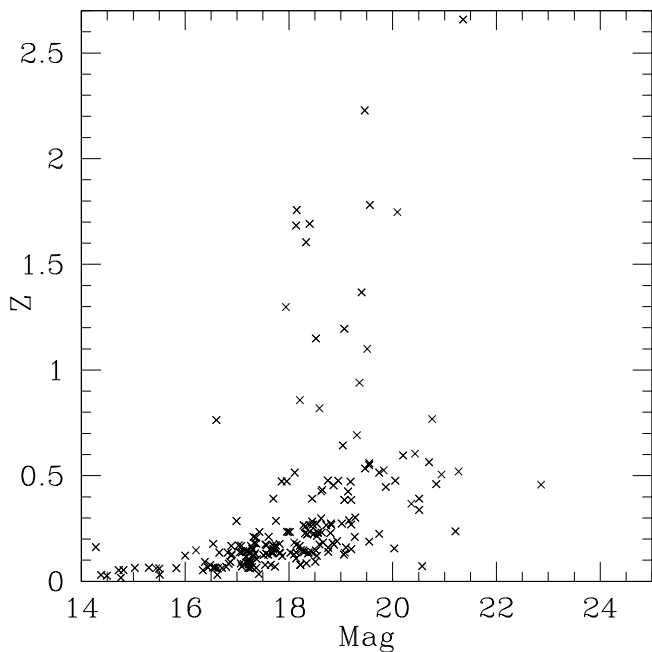


Figure 1.  $Z$  versus  $r'$  magnitude for all the objects with emission lines.

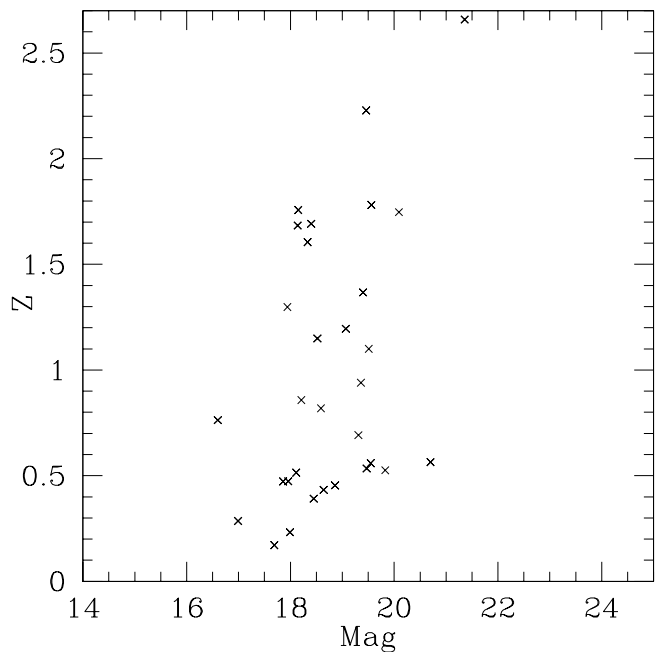


Figure 2.  $Z$  versus  $r'$  magnitude for objects with broad emission lines.

similar to the WYFFOS R600 gratings and exposure time of 120 minutes per pointing.

The reduction of the Hydra data has been made following the standard procedure with the Hydra package in IRAF. In the case of WYFFOS we used the WYFFOS package and other IRAF programs to take into account the different spectral resolution of the fibres and to improve the sky subtraction in the red part of the spectra ( $\lambda > 7000 \text{ \AA}$ ), where there are very bright sky lines (the reduction method will be explained in detail in Cabrera-Guerra *et al.* 2001 (in preparation)).

### 3. REDSHIFTS AND LUMINOSITIES

We have measured the redshift of objects showing emission lines in the fibre spectra. Figure 1 shows the redshifts and  $r'$ -band magnitudes of these objects. Objects with broad emission lines are shown in figure 2. All the high- $Z$  ( $Z \geq 0.8$ ) are type 1 AGN. A total of 222 objects show emission lines, including ISO and radio sources. The distribution of their redshifts is shown in figure 3. In figure 4 we show the 15 and 90  $\mu\text{m}$  luminosities as a function of redshift ( $H_0 = 50$ ,  $q_0 = 0.5$ ).

### 4. SPECTRAL CLASSIFICATION

The spectra obtained with WYFFOS and Hydra include objects of different type: galaxies without emission lines, starburst, type 1 and type 2 AGNs and some stars. In figure 5 we show some representative examples of ISO sources.

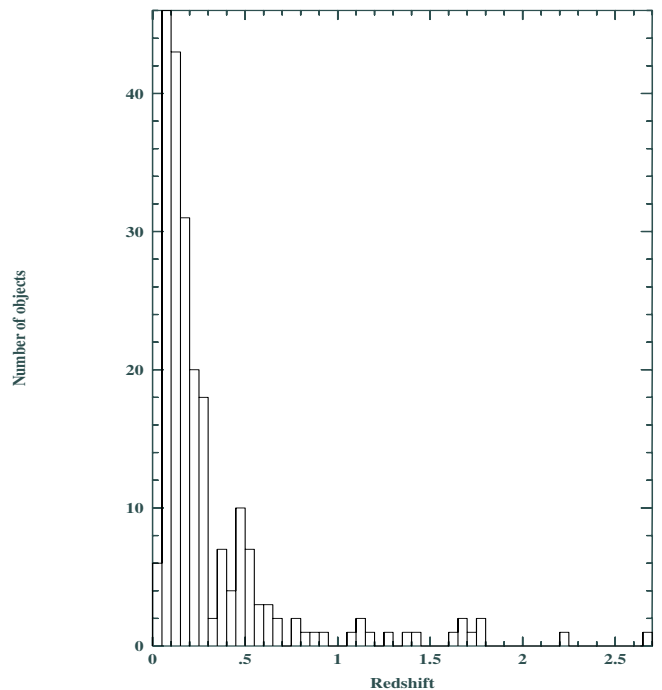


Figure 3. Distribution of redshifts of sources with emission lines.

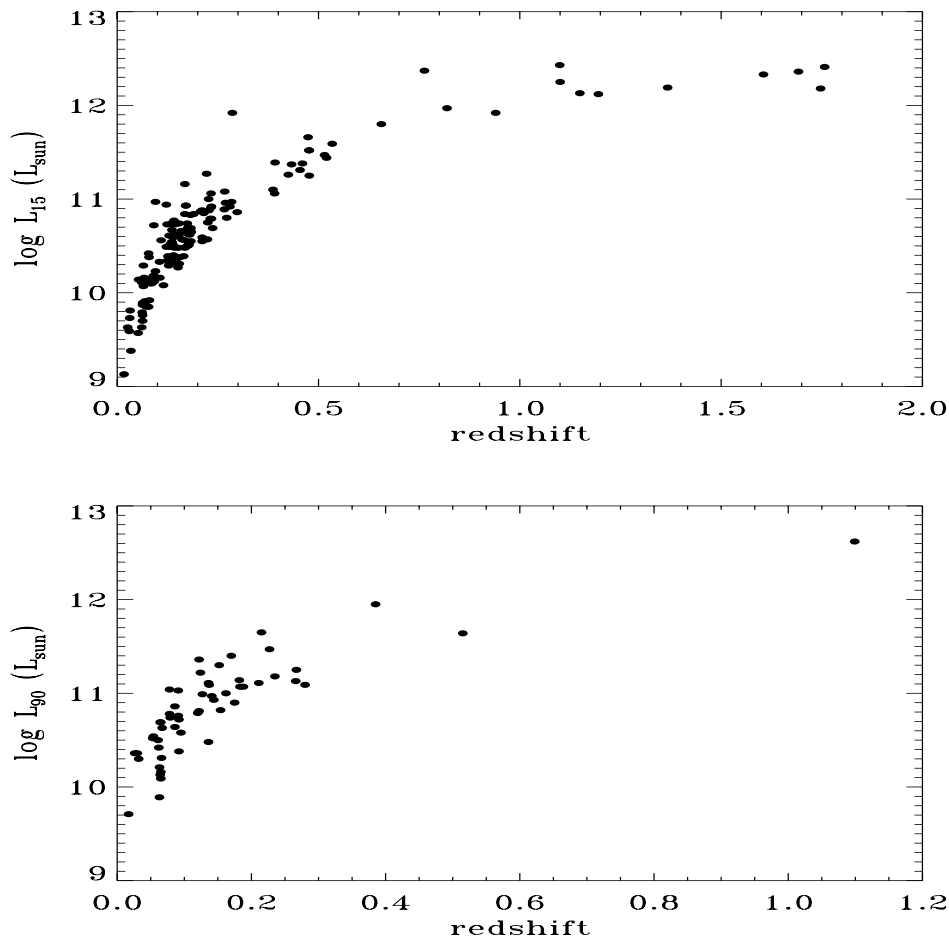


Figure 4. Luminosity at 15 and 90  $\mu\text{m}$  versus redshift

From the preliminary analysis of the spectra we detect 31 objects with broad lines (quasars and Seyfert 1 galaxies) and 188 narrow line objects (mainly starburst and Seyfert 2 galaxies). The remaining sample of observed objects includes galaxies without emission lines, objects with very low S/N and stars.

## 5. DISCUSSION

The depth of the ELAIS survey is small compared to other deeper ISO surveys. However, the large field of view and the multi-wavelength observations in the ELAIS areas allow us to explore also a large range of redshifts and object properties. For instance, a new hyperluminous IR galaxy has already been detected in our spectroscopic follow-up campaign (Morel *et al.* 2001). The results of these studies will be crucial for other surveys in these regions with the future generation of mid- and far-IR space telescopes, such as SIRTf, NGST and FIRST. The ELAIS N1, N2 and S1 regions are being considered for SIRTf observations as part of one of the Legacy Science programs, the SIRTf Wide-Area InfraRed Extragalactic Survey (SWIRE, PI

Carol Lonsdale). A survey with the Herschel FIRST observatory in these areas would also benefit from the available imaging and spectroscopic data, and the future near-, mid- and far-IR observations of these fields with SIRTf.

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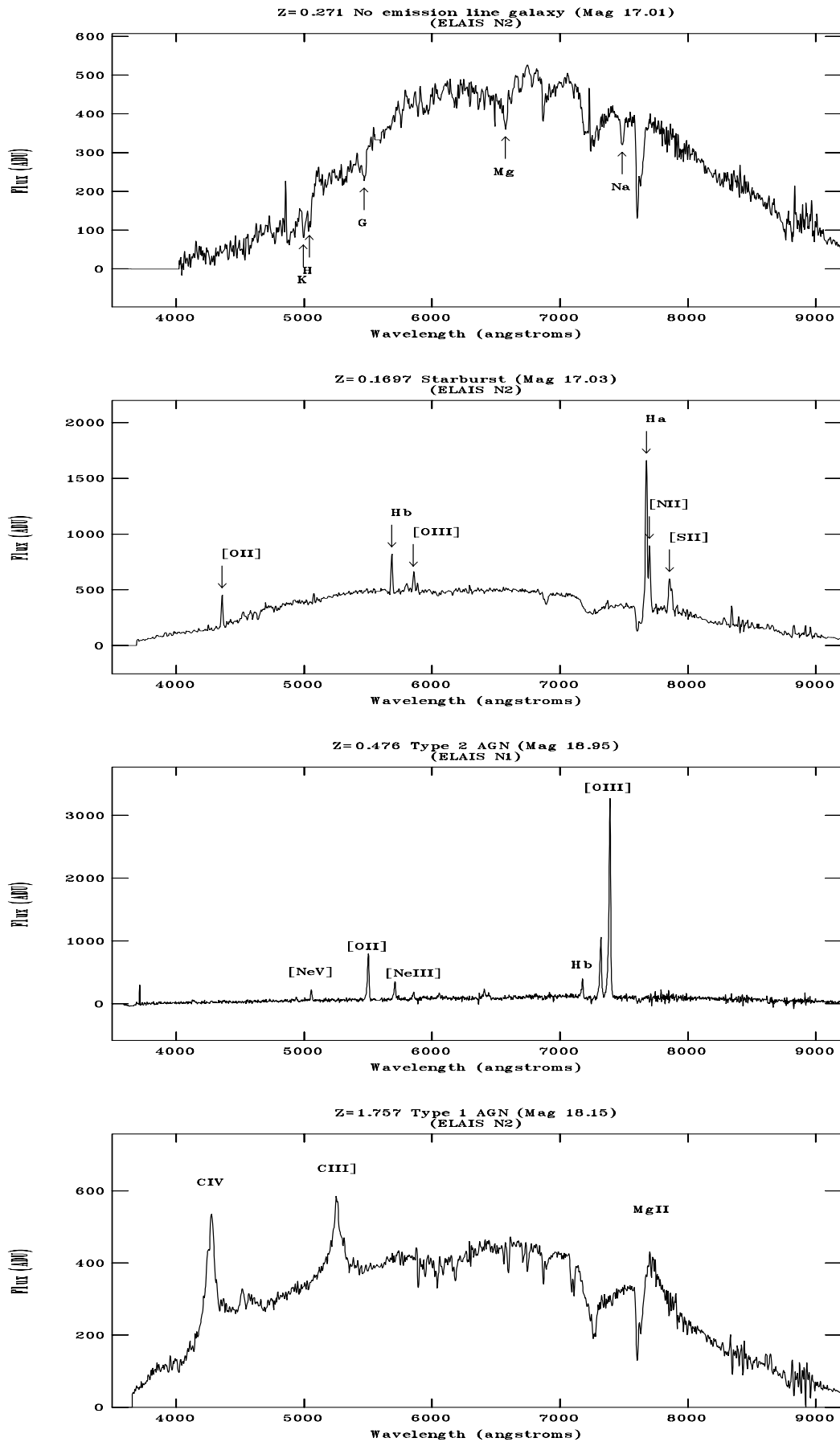


Figure 5. Typical spectra of different kind of objects observed.