A 15 μm Selected Sample of High-z Starbursts and AGNs

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Abstract. We report results from our *Spitzer* GO-1 program on IRS spectroscopy of a large sample of Luminous Infrared Galaxies and quasars selected from the European Large Area ISO Survey (ELAIS). The selected ELAIS sources have a wide multi-wavelength coverage, including ISOCAM, ISOPHOT, IRAC and MIPS (from SWIRE), and optical photometry. Here we present the sample selection and results from the IRS spectroscopy.

1. Sample Selection and IRS Observations

The sources were selected from the European Large Area ISO Survey (ELAIS) final band-merged catalog of Rowan-Robinson et al. (2004). The sample consists of 70 sources with 15 μm fluxes larger than ~ 1 mJy and spectroscopic or estimated photometric redshifts $z > 1$. Although no color cuts were applied, the objects are brighter than $r \sim 24$, the limit of the Isaac Newton Telescope Wide Field Survey CCD photometry used in the optical identification of ELAIS sources (González-Solares et al. 2005). The 15 μm observations and catalog are
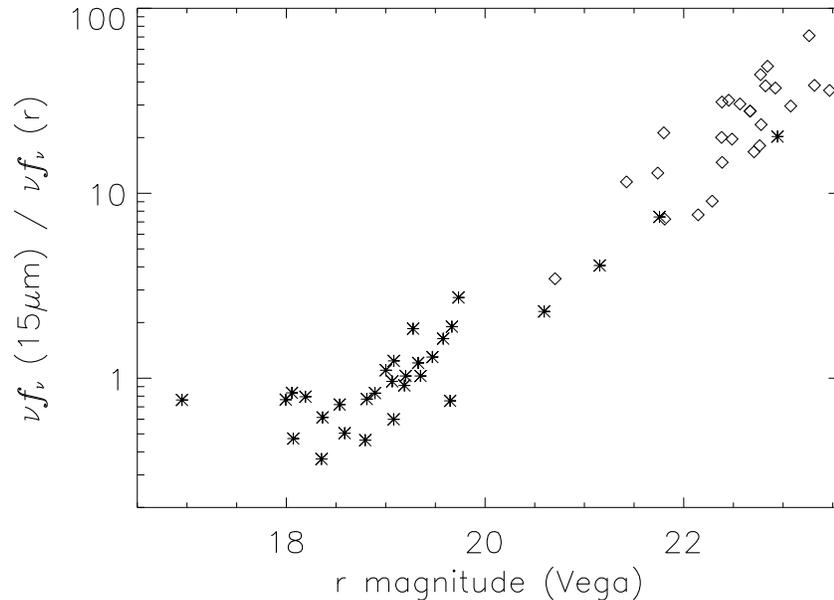
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Figure 1.   Ratio νf_ν (15 μm) / νf_ν (r) for the ELAIS-IRS sources versus r-band magnitude. Diamonds: star-forming galaxies and obscured AGN; stars: unobscured AGN.

presented in Vaccari et al. (2005).

Low-resolution IRS spectroscopy was carried out using all four IRS modules, covering thus the wavelength range between 5 and 40 μm. Typical total exposure time per object was of about one hour. Figure 1 shows the ratio of νf_ν at 15 μm over r-band as a function of the r-band magnitude. ELAIS-IRS targets with bright magnitudes have blue optical to 15 μm colors typical of type-1 AGN (Afonso-Luis et al. 2004; González-Solares et al. 2005; Hatziminaoglou et al. 2005). Objects with fainter optical IDs are identified as obscured AGN and star-forming galaxies.

2.   Results from the IRS Spectroscopy

The IRS spectra were extracted from the SSC pipeline processed data using SPICE, and individual spectra of each object were coadded. A selection of the IRS spectra is shown in figure 2. The IRS spectra show a wide variety of spectral shapes and clear features (PAHs in emission and silicate absorption at 9.7 μm) can be seen in a number of objects. The IRS spectra can be classified into three main categories: (a) smooth featureless continuum, usually associated with type-1 AGN, (b) PAH features in emission and silicate absorption, and (c) silicate absorption.
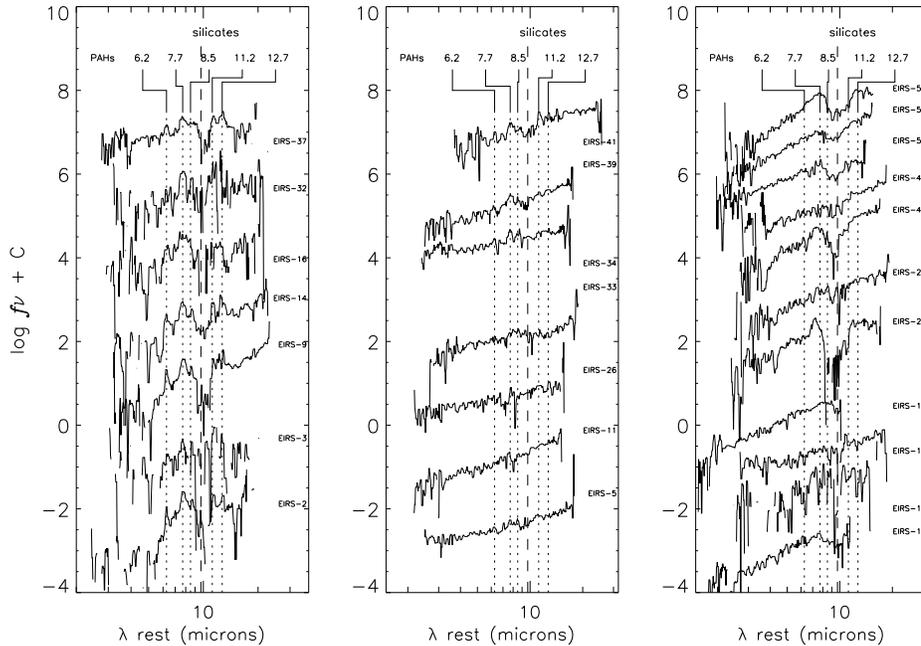
Figure 2. A selection of ELAIS-IRS spectra showing different types of mid-IR SEDs, including strong PAH, star-forming dominated SEDs (left), power-law continua with or without PAH features (center) and silicate absorption (right).

Redshifts can be measured for a number of objects from the IRS spectroscopy, and they agree with the optical spectroscopic redshifts, whenever available. They are also consistent in most cases with the photometric redshifts obtained from template fitting to the optical and IRAC photometry from SWIRE (Lonsdale et al. 2003, 2004). Objects in our sample with PAH features and starlight-dominated optical SEDs are interpreted as star-forming galaxies. Their redshifts are in the range $0.6 < z < 1.2$ and the far-IR (8-1000 μm) luminosities are in the range $\sim 10^{11} - 10^{12} L_\odot$.

Some galaxies are found at higher redshifts, up to z $\sim$ 2. They only show silicate in absorption and no bright PAH features. Their luminosities are in the ULIRG range. Their SEDs and IRS spectra suggest they are obscured AGN.

3. Comparison with Other IRS Samples of High-z Galaxies

Our sample, selected at 15 μm from the ELAIS survey, differs in redshift range and luminosity from those in other major IRS surveys (fig. 3). The sample selection of Yan et al. (2005) was based in color cuts using the Spitzer 24 and 8 μm bands and one optical band (R), while Houck et al. (2005) selected objects with very red 24 μm to R band colors. Our ELAIS-IRS sample selection aims to cover all possible types of z $\gtrsim$ 1 sources selected at 15 μm, regardless of their
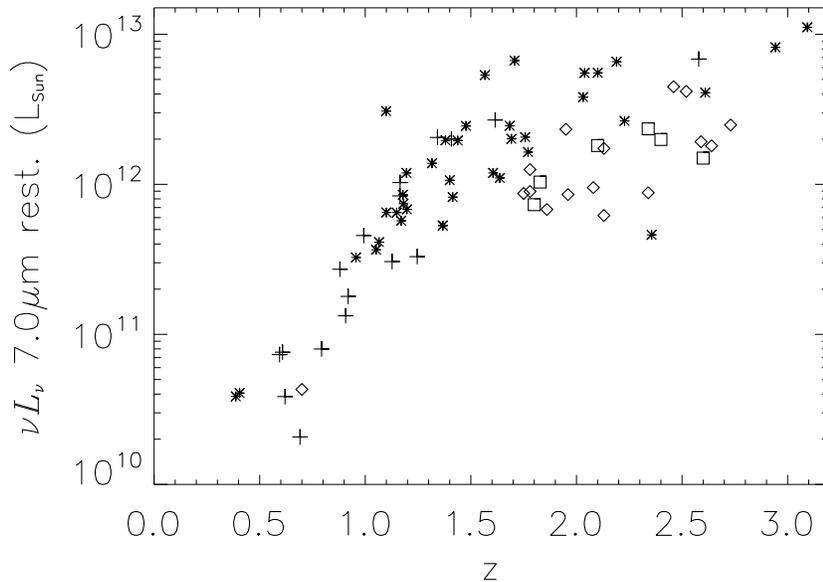
Figure 3. Restframe 7 μm luminosity (νL_ν) versus redshift for the ELAIS-IRS sample. Objects with optical spectroscopic redshifts (mostly AGN) are shown as stars, whereas those with z estimated from their IRS spectra are plotted as plus signs. For comparison, samples from Yan et al. (2005) and Houck et al. (2005) are represented as squares and diamonds, respectively.

mid-IR colors. The results show that a large fraction of the star-forming galaxies in the sample is at z $\sim$ 1, as expected from the photometric redshifts estimates, and is consistent with bright PAH features (7.7 and 8.5 μm) redshifted into the ISOCAM LW3 band (15 μm). At low redshift (z $<$ 1) our sample includes luminous infrared star-forming galaxies and two AGN at intermediate redshifts (1.0 $< z <$ 1.8) we find AGN, both obscured and unobscured, and star-forming galaxies, all with restframe 7 μm luminosities comparable to those in the Yan et al. (2005) and Houck et al. (2005) samples. At z $\gtrsim$ 1.8 we find AGNs, typically more luminous than the comparison IRS samples.

The ELAIS-IRS sample constitutes one of the best samples of luminous and ultraluminous IR sources with IRS spectroscopy in the redshift range (0.5 $<$ z $<$ 1.8). A number of spectroscopic follow-up programs are underway. The ELAIS-IRS sample and detailed results are presented in Hernán-Caballero et al. (2006).

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