A 15 \( \mu m \) Selected Sample of High-z Starbursts and AGNs

A. Hernán-Caballero,\(^1\) I. Pérez-Fournon,\(^1\) M. Rowan-Robinson,\(^2\) D. Rigopoulou,\(^3\) A. Afonso-Luis,\(^1\) E. Hatziminaoglou,\(^1\) E. González-Solares,\(^4\) F. M. Montenegro-Montes,\(^5\) B. Vila-Vilaro,\(^6\) D. Farrah,\(^7\) C. Lari,\(^5\) M. Vaccari,\(^2\) T. Babbedge,\(^2\) S. Oliver,\(^8\) D. Clements,\(^2\) S. Serjeant,\(^9\) F. Pozzi,\(^10\) F. La Franca,\(^11\) C. Gruppioni,\(^10\) I. Valtchanov,\(^2\) C. Lonsdale\(^7\) and the SWIRE team

\(^1\)Instituto de Astrofísica de Canarias, 38200 La Laguna, Tenerife, Spain
\(^2\)Astrophysics Group, Blackett Laboratory, Imperial College London, Prince Consort Road, London SW7 2BZ, UK
\(^3\)Department of Astrophysics, Oxford University, Keble Road, Oxford OX1 3RH, UK
\(^4\)Institute of Astronomy, University of Cambridge, Madingley Road, Cambridge CB3 0HA
\(^5\)Istituto di Radioastronomia, INAF, via Gobetti 101, I-40129 Bologna, Italy
\(^6\)National Observatory of Japan 2-21-1 Osawa, Mitaka, Tokyo 181-8588, Japan
\(^7\)Department of Astronomy, Cornell University, Ithaca, NY 14853
\(^8\)Astronomy Center, University of Sussex, Brighton BN1 9QH, UK
\(^9\)Centre for Astrophysics & Planetary Science, School of Physical Sciences, University of Kent, Canterbury, Kent CT2 7NR, UK
\(^10\)INAF, Osservatorio Astronomico di Bologna, via Ranzani 1, 40127 Bologna, Italy
\(^11\)Dipartimento di Fisica, Universit Roma Tre, via della Vasca Navale 84, 00146 Roma, Italy

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 \( \mu m \) fluxes larger than \( \sim 1 \) 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 \( \mu m \) observations and catalog are
Figure 1. Ratio $\nu f_\nu (15 \mu m) / \nu f_\nu (r)$ for the ELAIS-IRS sources versus $r$-band magnitude. Diamonds: star-forming galaxies and obscured AGN; stars: unobscured AGN.

Low-resolution IRS spectroscopy was carried out using all four IRS modules, covering thus the wavelength range between 5 and 40 $\mu$m. Typical total exposure time per object was of about one hour. Figure 1 shows the ratio of $\nu f_\nu$ at 15 $\mu$m over $r$-band as a function of the $r$-band magnitude. ELAIS-IRS targets with bright magnitudes have blue optical to 15 $\mu$m 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 $\mu$m) 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.
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 $\mu$m) 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 $\mu$m 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 $\mu$m bands and one optical band (R), while Houck et al. (2005) selected objects with very red 24 $\mu$m to R band colors. Our ELAIS-IRS sample selection aims to cover all possible types of $z \gtrsim 1$ sources selected at 15 $\mu$m, regardless of their
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 redshift estimates, and is consistent with bright PAH features (7.7 and 8.5 $\mu$m) redshifted into the ISOCAM LW3 band (15 $\mu$m). 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 $\mu$m 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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References

Hernán-Caballero, A. et al. 2006, in preparation