DEEP OPTICAL AND NEAR INFRARED OBSERVATIONS IN ELAIS AREAS

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Abstract

We present deep optical and near infrared imaging over half square degree of sky in the centres of the ELAIS regions N1 and N2 and coincident with deep XMM/Chandra observations. The data have been obtained with the Wide Field Camera (WFC) and the Cambridge InfraRed Survey Instrument (CIRSI) both at the Isaac Newton Telescope (Observatorio del Roque de los Muchachos, Canary Islands). Limiting magnitudes achieved are g'=26.7, r'=26.2, i'=25.0 and H=20.2 (3σ). These data have been used to identify the faint optical counterparts of the Infrared Space Observatory (ISO), radio and X-ray sources in these areas.

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

1. Introduction: The ELAIS survey

The European Large Area ISO Survey (ELAIS; Rowan-Robinson et al. 1999, Oliver et al. 2000) is a collaboration involving 25 European institutes. This project surveyed around 12 square degrees of high latitude sky at 15 and 90μm, nearly 6 square degrees at 6.7μm and one square degree at 175μm. The survey used the ISO Camera (ISOCAM) at the two shorter wavelengths and the ISO Photometer (ISOPHOT) at the longer wavelengths. ELAIS was the largest open time project undertaken with ISO, a total of 375 hours of scientifically validated data have been produced. We have detected over 1000 extragalactic objects and a similar number of galactic sources.

The ISO observations together with the extensive follow-up programmes carried out have made the ELAIS fields excellent areas for surveys at other wavelengths. These include radio observations (Ciliegi et al. 1999), optical and near-IR and sub-mm. A spectroscopic program to observe optical counterparts of ISO and radio sources has also been recently carried out (Pérez-Fournon et al. 2001, in prep; Cabrera-Guerra et al. these proceedings). The Chandra X-ray Observatory (CXO) has also observed the central part ($\sim 16' \times 16'$) of the N1 and N2 regions with deep integrations of 75 ksec in each field (Almaini et al. 2001, in prep). The XMM-Newton satellite will also target the same fields observed by CXO over larger areas.

The ELAIS N1 and N2 fields are included in the SIRTF Wide Area InfraRed Extragalactic Survey (SWIRE; P.I. Carol Lonsdale), selected for the SIRTF Legacy Program and are also ideal fields for extragalactic surveys with FIRST.

For a larger review on ELAIS and the follow-up carried out in the N1 and N2 areas see Pérez-Fournon et al. in these proceedings.

2. Optical Observations

Optical observations were carried out in July 2000 at the Isaac Newton Telescope using the Wide Field Camera (WFC). The WFC comprises 4 thinned coated chips 2048×4096 pixels each. The scale is $0.333''$/pix and the field of view of the camera is about $30' \times 30'$. In order to remove the gaps between chips, we obtained single frames of 10 minutes exposure time following a dither pattern of $20''$ separation. We selected two regions centred on the N1 and N2 ELAIS areas. Exact pointings were selected to be coincident with those of planned XMM-Newton and CXO X-ray observations. The aim was to obtain deep optical imaging in three bands: g', r' and i'. Total integration time was about 1 hour in each band. Data reduction used the Wide Field Survey (WFS; McMahon et al. 1999) pipeline developed at IoA, Cambridge and includes bias and flatfield correction, defringing of i' band images, non linearity corrections and astrometry. Mosaicing of the images was done using the IRAF task MSCRED. Limiting magnitudes achieved are g'=26.7, r'=26.2 and i'=25.0 (3σ limit). A detailed description of these observations can be found in González-Solares et al. 2001a, in prep.

3. Near-IR Observations

Near infrared observations have been carried out using the Cambridge InfraRed Survey Instrument (CIRSI) at the INT telescope. The CIRSI camera (Beckett et al. 1996)

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ESA SP-460, July 2001, eds. G.L. Pilbratt, J. Cernicharo, A.M. Heras, T. Prusti, & R. Harris

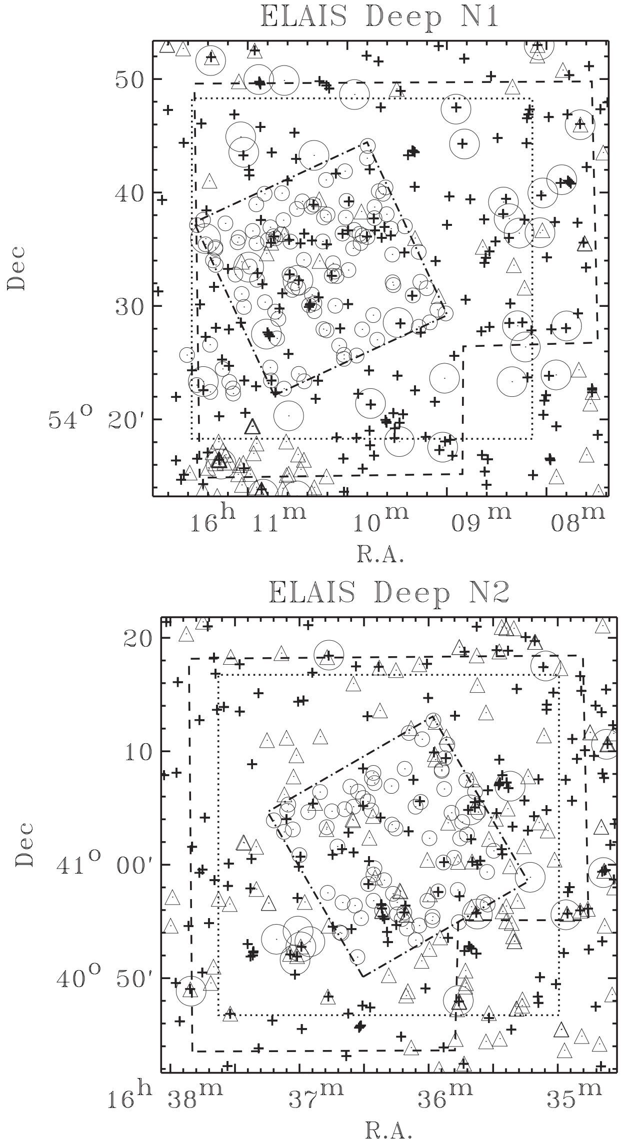

Figure 1. Optical and near-IR observations carried out in the central parts of the ELAIS N1 and N2 areas. Figures show the sources detected by ISO (triangles - 15μm - and large circles - 90μm -), radio sources detected at 20cm (crosses) and X-ray sources detected by CXO (small circles). Large squares show the area covered in the optical (dashed line), near infrared (dotted) and X-ray (dash-dot line).

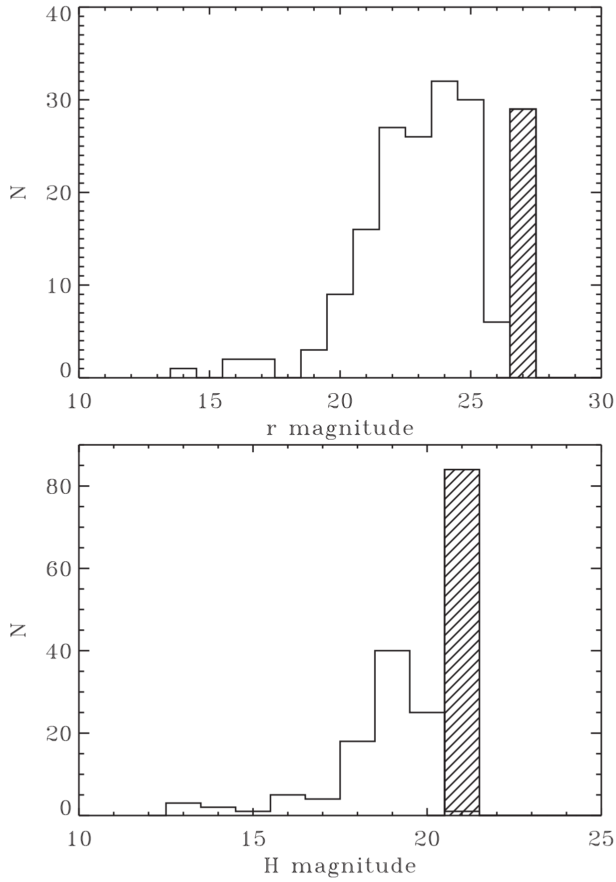

Figure 2. Magnitude distributions of detected CXO X-ray sources in our deep images. Hatched region correspond to the non detected sources.

comprises 4 chips 1024 × 1024 pixels each with gaps between them of size sligthly smaller than the chip size. The scale at the telescope is $0.457''$/pix and correspondingly chip sees an area of about $8' \times 8'$. In order to cover a contiguous $30' \times 30'$ area of sky, four individual pointings are needed. With 10 minutes exposure per pointing CIRSI is able to cover a $30' \times 30'$ are in 40 minutes to a depth of H=19.2 at the INT prime focus. We have observed an area of ~ 2 square degrees in N1 and N2 to this limit. In the central regions of N1 and N2 we aimed to reach at least one magnitude deeper than this so we observed for about 1 hour per pointing to reach a depth of H=20.2 (3σ). Description of observations, reduction procedures and number counts are presented in González-Solares et al. 2001b (in prep).

In figure 1 we show the multi-wavelength coverage available in our ELAIS deep fields N1 and N2. Catalogues from our optical and near-IR observations have been built using SExtractor (Bertin & Arnouts 1996) and they have been correlated with radio, ISO and CXO catalogues.

4. Identification of X-ray sources

Identification of the preliminary list of X-ray sources has been carried out by searching for the nearest optical or near-IR objects. Figure 2 shows the r' and H magnitude distributions. About 10% of the X-ray sources remain identified in our optical deep r' band image. According to SExtractor morphological classification about 40% of the sources appear point-like in our images while about 30% are extended. Figure 3 shows r'-H color versus r' magnitude for sources detected in both bands. Optically faint CXO X-ray sources have very red colors up to r'-H$\sim$7.

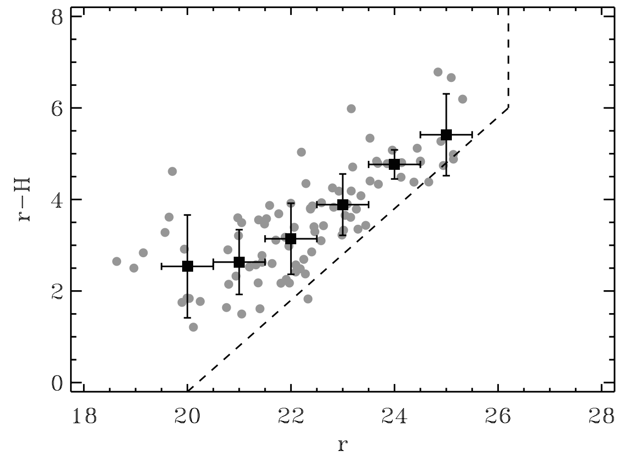

Figure 3. r'-H versus r' color diagram for the 80% sources detected in both bands. Dark squares show the mean <r'-H> in each r' magnitude bin and dashed lines show the detection 3σ limit.

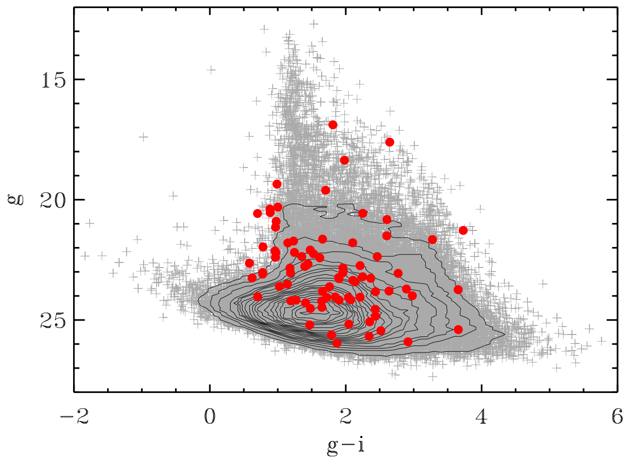

Figure 5. g' versus g'-i' diagram for detected CXO sources compared with all the field objects detected.

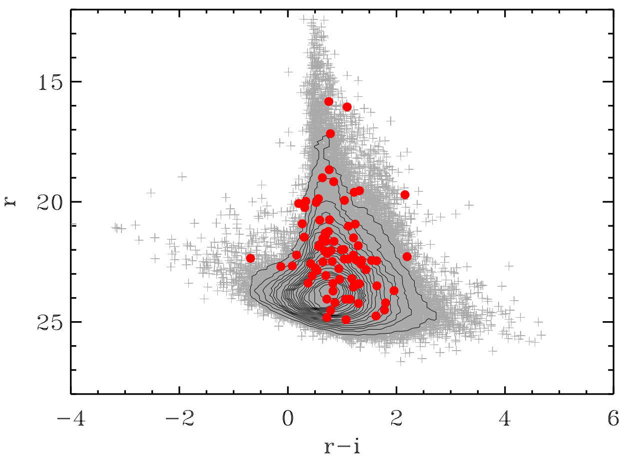

Figure 4. r' versus r'-i' diagram for detected CXO sources compared with all the field objects detected. Contours represent the density of objects, linearly spaced in color-magnitude space.

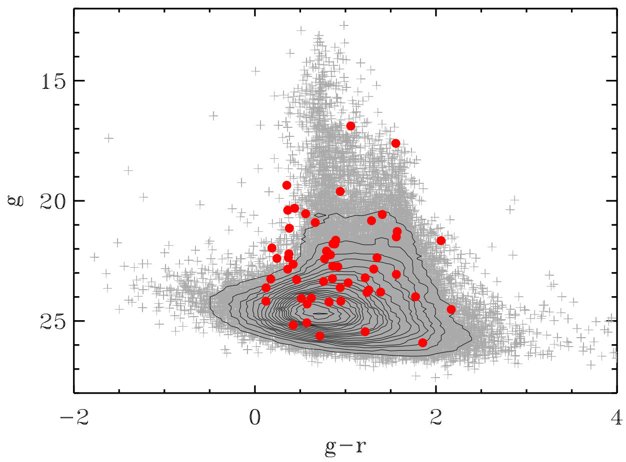

Figure 6. g' versus g'-r' diagram for detected CXO sources compared with all the field objects detected.

These results are in agreement with those obtained in the Chandra Deep Field South (Giacconi et al. 2000).Figures 4, 5, 6 and 7 show the location of the CXO sources in the optical magnitude and color-color diagrams with respect to field objects.

5. Conclusions

We describe deep optical and near-IR observations of two areas located in the centres of ELAIS N1 and N2 regions and coincident with X-ray Chandra observations. We have obtained deep g', r', i' and H band images. In these paper we show the optical to near-IR properties of the X-ray Chandra sources identified. In the near future we will add to our multi-wavelenth database observations in the U and z bands. This will allow us to achieve a better characterization of the X-ray sources in the multi-wavelength space as well as the determination of photometric redshifts.

The extensive follow-up carried out in the ELAIS areas has made them excellent regions with multi-wavelength coverage. These areas will be observed by SIRTF as part of the SWIRE Legacy Program and are also excellent survey areas for FIRST. The data we have obtained has allowed us to identify the faintest ISO sources as well as the faint radio and CXO X-ray sources and prepare their spectroscopic followup.

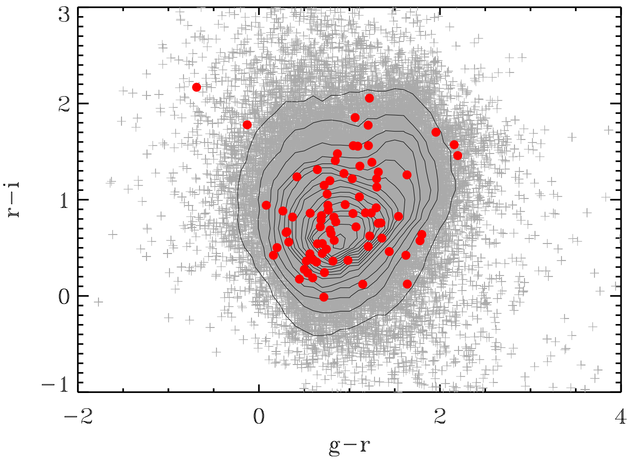

Figure 7. g'-r' versus r'-i' diagram for detected CXO sources area compared with all the field objects detected.

6. Acknowledgements

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