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AKARI ALL-SKY BRIGHT SOURCE CATALOGUE: FAR-INFRARED LUMINOUS QUASARS AND THE OPTICAL FAR-INFRARED CORRELATION

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ABSTRACT

We have identified 22 quasars in the *AKARI* far-infrared all-sky Bright Source Catalogue, using a matching radius of $< 10''$, and excluding matches which are close to foreground extended sources or cirrus. We have confirmed a relation between quasar optical luminosity and far-infrared luminosity which was found in an earlier study. In addition, we have found that the 11 sources which are at redshift $z > 1$ are magnified with respect to the predicted far-infrared luminosity, and consider this may be due to gravitational lensing. If confirmed, this would provide a new way to identify lenses; if not, we may have identified an interesting new population of extreme starbursting quasars.

Key words: cosmology:observations; galaxies:evolution; galaxies:active; infrared:galaxies

1. INTRODUCTION

Investigating the relationship between the luminosity from black hole accretion and the luminosity from star formation in quasars has been limited in the past by the relatively small number of sources for which both sets of data are available. Earlier work has attempted to overcome this deficiency by using stacking analysis, often of sources observed at a variety of far-infrared (FIR) and submillimetre wavelengths (Serjeant & Hatziminaoglou, 2009; Serjeant et al., 2010; Bonfield et al., 2011). This has led to the discovery of a correlation between the optical luminosity (primarily due to the quasar) and the FIR luminosity (primarily due to star formation). In particular, there is a steeper fall-off in the FIR than in the optical wavelengths at the higher luminosity end of their luminosity functions (Figure 1).

The *AKARI* all-sky survey mission (Murakami et al., 2007), which provided the first census of the infrared sky since that of the Infra-Red Astronomical Satellite (IRAS) in 1983, has provided a database of over 425,000 FIR sources at four FIR wavelengths, including at 90 μm, close to the FIR peak from dust re-emission of radiation from star formation. This survey, the Bright Source Catalogue (BSC; Yamamura et al., 2009), covered about 98% of the sky.

2. QUASAR CATALOGUES

We have matched both spectroscopic and photometric quasar catalogues to the *AKARI* BSC far-infrared catalogue.

The Sloan Digital Sky Survey (SDSS) DR7 Quasar Catalogue (Schneider et al., 2010) contains 105,783 quasars. SDSS-III BOSS has produced a quasar catalogue covering the redshift range 2.15<z<3.5: DR9 (Paris et al., 2012) contained 87,822 sources (78,086 new discoveries). The DR10 quasar catalogue will be available shortly. We also matched to 2SLAQ, Palomar Green and Hamburg/ESO spectroscopic quasar catalogues. A total of 33 matches were found. After

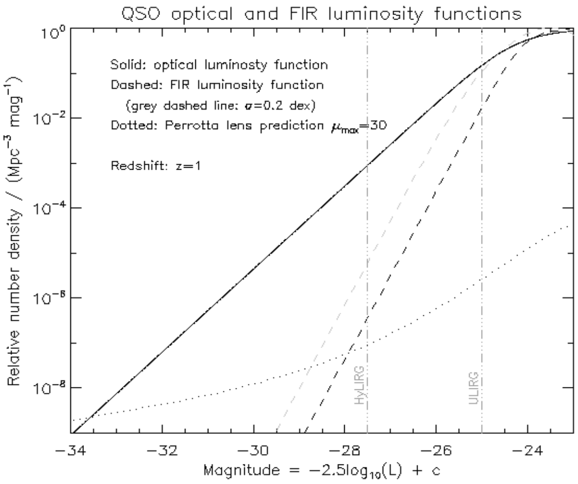

Figure 1. Relative optical and FIR luminosity functions for quasars for $z = 1$ assuming the concordance cosmology. The optical luminosity functions are from Croom et al. (2004). The FIR luminosity functions are calculated from the Serjeant et al. (2010) relation for 100 μm. Note the relative drop in the FIR LF at higher luminosity, which is even more pronounced at higher redshift. The lensed prediction is based on the formalism of Blain (1996) and Perrotta et al. (2002; 2003). Lensed systems dominate above the HyLIRG level.

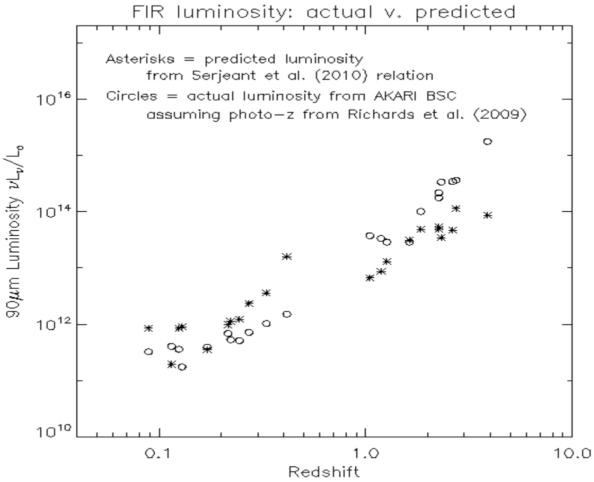

Figure 2. Actual *AKARI* BSC luminosity vs. prediction using the Serjeant et al. (2010) relation for our final shortlist of 22 matches shown by redshift. Magnification is shown for sources at $z > 1$, suggesting possible gravitational lensing.

examining optical images from the SDSS archive, 23 were judged to be local sources, leaving 10 spectroscopic quasar/FIR matches.

Distinguishing quasars from stars is much more difficult than distinguishing them from galaxies, so most studies of quasars have been based on their identification by spectroscopic evidence. Early attempts to provide a more extensive quasar catalogue not reliant on spectroscopic data identified quasars by the UV-excess method, but achieved an efficiency of only about 50% (e.g. Croom et al., 2001). However, several projects are now underway using techniques such as Bayesian selection algorithms and neural networks to make the identifications from photometric catalogues with greater identification efficiency.

The most extensive photometric quasar catalogue which includes (photometric) redshifts is the Nonparametric Bayesian Classification Kernel Density Estimator (NBCKDE; Richards et al., 2009) which is based on SDSS Data Release 6 (Adelman-McCarthy et al., 2008). We matched the BSC sources to the Richards catalogue, which has 1,172,157 quasar candidates and estimates identification efficiency of about 80%. We found 584 BSC matches, of which 256 had quality flags greater than or equal to zero. From an examination of optical images from the SDSS archive, roughly ninety per cent of these sources showed extended local features: some FIR sources were either in local spiral or irregular galaxies (some were bright spots in spiral arms, suggesting HII regions) or within the *AKARI* pixel size (about 8′′) of an extended local source. Some sources were identified as Galactic cirrus features. After excluding these, we were left with 20 matches to the Richards catalogue, 8 of which were also matched to one of the spectroscopic catalogues discussed above, bringing our final total of candidates to 22.

3. METHODS AND RESULTS

Stacking analysis of the initial observations from Herschel (Serjeant et al., 2010) has given the following relationship between 100 μm luminosity and absolute magnitude in the I-band for quasars:

$$log_{10}\frac{\nu L_\nu(100\mu m)}{10^{12}L_\odot} = \alpha(M_I + \beta) \qquad (1)$$

with the parameter values for z<4 being $\alpha(z) = (0.0371 \pm 0.0048)z - (0.235 \pm 0.018)$ and $\beta(z) = (-1.19 \pm 0.30)z + (27.42 \pm 0.37)$. For sources with $z > 4$ the values at z=4 were used. To convert the Serjeant formula from 100 μm to 90 μm, we have used a factor of 1.197 which is the νS_ν ratio from the M82 SED.

The relative optical and FIR luminosity functions resulting from the Serjeant relation are shown in Fig. 1 for $z = 1$. The FIR luminosity falls off sharply compared to the optical luminosity, and this becomes sharper at higher redshift.

We have used the optical luminosities of the sources and their redshifts to predict the FIR luminosity using the Serjeant relation, and this is plotted as a function of redshift together with the actual 90 μm luminosity from *AKARI* in Fig. 2. The observed slope is similar to the predicted slope. The actual values are close to or lower than the predicted values for $z < 1$. For sources at $z > 1$, however, observed values are higher than predicted in every case, suggesting the flux from these sources may be magnified by gravitational lenses. Magnification by a lens would give a higher relative FIR luminosity, since there would not be the drop off at higher luminosity predicted by the Serjeant et al. (2010) relation. If so, it provides a new method for identifying lenses by selecting quasars with strong FIR luminosity; if not, it identifies a new population of extreme starbursting quasars.

Further work is underway to spectroscopically confirm the redshifts of these $z > 1$ sources, and to obtain better optical images.

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