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Mid-infrared selection of Quasar-2s in Spitzer's First Look Survey

Mark Lacy[1], Gabriela Canalizo[2], Steve Rawlings[3], Anna Sajina[4],
Lisa Storrie-Lombardi, Lee Armus, Francine R. Marleau, Adam Muzzin[1]

[1] Spitzer Science Center, California Institute of Technology, MS220-6, 1200 E. California Boulevard, Pasadena, CA 91125, USA e-mail: mlacy@ipac.caltech.edu
[2] University of California, Riverside, CA, USA
[3] Astrophysics, University of Oxford, UK
[4] Astronomy, University of British Columbia, Canada

Abstract. We present early results from the spectroscopic follow-up of a sample of candidate obscured AGN selected in the mid-infrared from the Spitzer First Look Survey. Our selection allows a direct comparison of the numbers of obscured and unobscured AGN at a given luminosity for the first time, and shows that the ratio of obscured to unobscured AGN at infrared luminosities corresponding to low luminosity quasars is $\approx 1:1$ at $z \sim 0.5$. Most of our optically-faint candidate obscured AGN have the high-ionization, narrow-line spectra expected from type-2 AGN. A composite spectrum shows evidence for Balmer absorption lines, indicating recent star-formation activity in the host galaxies. There is tentative evidence for a decrease in the obscured AGN fraction with increasing AGN luminosity.

Key words. galaxies:active – infrared radiation – galaxies:distances and redshifts

1. Introduction

The question of how many quasars are obscured by dust is still to be resolved. Despite some success with samples selected in the hard X-ray (e.g. Norman et al. 2002), in the near-infrared from 2MASS (Cutri et al. 2002, Glikman et al. 2004) and from the Sloan Digital Sky Survey (SDSS) (Zakamska et al. 2004), there is still no consensus on the number densities and luminosity distribution of the hidden quasar population, particularly at high (quasar-like) luminosities. There are a number of reasons for this. In the X-ray, it is still unclear what fraction of high luminosity AGN might be Compton thick. 2MASS selection suffers from not being able to select the most heavily-extincted objects, and the SDSS selection on the basis of narrow lines has potentially complex selection biasses. All these techniques suffer from much uncertainty in relating the number densities of quasars to those of quasar-2s when the two types of object are selected in quite different ways.

The fraction of hidden quasars is, however, important to establish if we are to relate the mass density in black holes today to the accretion onto black holes in the past (e.g. Yu & Tremaine 2002). In particular, any explanation

Send offprint requests to: Mark Lacy
Correspondence to: MS220-6, 1200 E. California Boulevard, Pasadena, CA 91125, USA

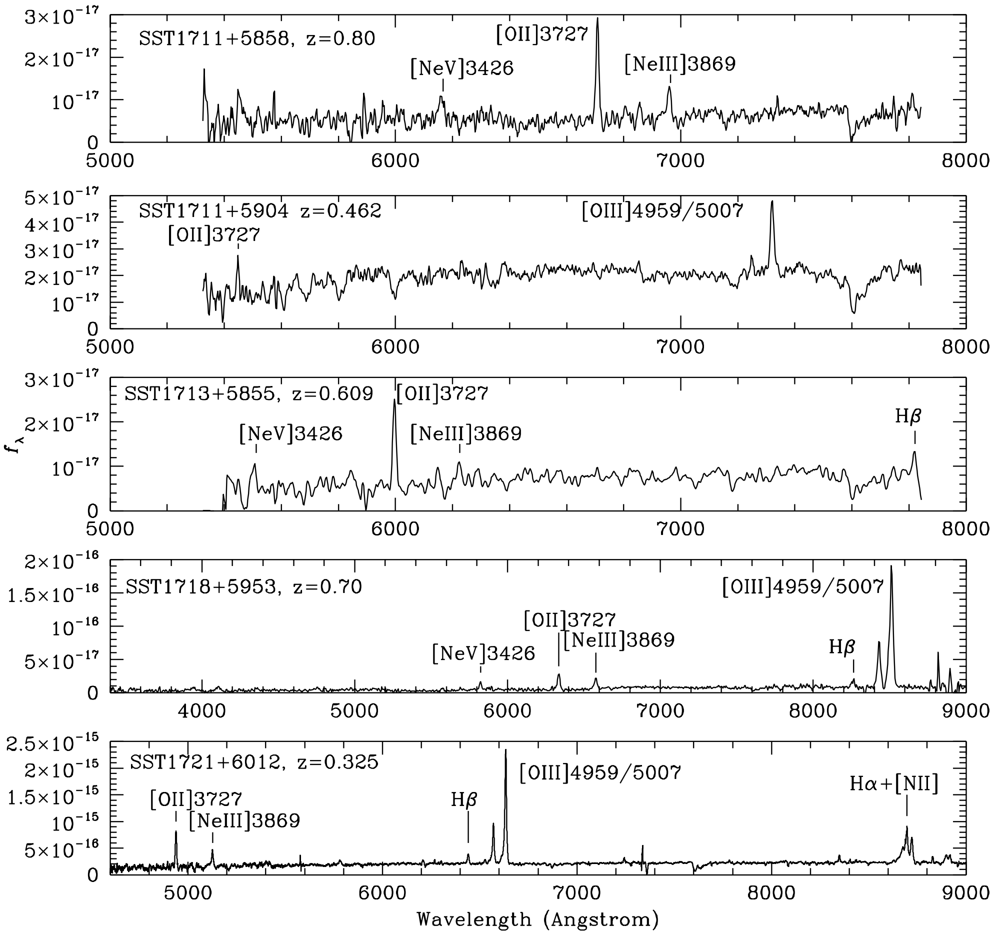

Fig. 1. Optical spectra of the six most infrared-luminous of our objects to show the high-ionization, narrow-line spectra associated with type-2 AGN.

for the close relationship between galaxy bulge velocity dispersions and central black hole masses (e.g. Gebhardt et al. 2000) involves an understanding of how black hole mass accretion varies with epoch and host galaxy mass in both obscured and unobscured AGN. In Lacy et al. (2004; hereafter Paper 1) we presented a technique for selecting obscured AGN using only mid-infrared colours. The advantage of this technique is that type-1 and type-2 AGN can be selected using the same criteria, removing the uncertainty involved when type-1 and type-2 objects are selected in different ways. The effectiveness of this technique for selecting AGN in *Spitzer* surveys has been confirmed by Stern et al. (2004) and Hatziminaoglou et al. (2004). In table 1 of Paper 1 we presented a list of candidate obscured AGN. In this paper we present early results from the spectroscopic follow-up of these objects.

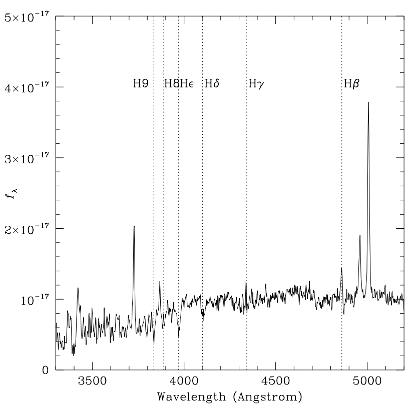

Fig. 2. Composite spectrum showing Balmer absorption features in the host galaxies.

2. Optical spectroscopy

Optical spectra were taken of twelve of the obscured AGN in Paper 1, concentrating on the fainter identifications most likely to be quasar-2s. The results are shown in Table 1 and Fig. 1. Most objects have the high-ionization, narrow-line spectra expected for quasar-2s, with several either containing the [Nev]3426 emission line, or having sufficient emission lines to place them firmly amongst the AGN in the diagnostic diagram of Kauffmann et al. (2003).

3. Luminosities of the obscured AGN

Using the redshifts, we can estimate the luminosities of our obscured AGN. The mean ratio between the B-band and 5μm luminosity density for quasars is about 10 (Elvis et al. 1994), so a type-1 AGN on the quasar-Seyfert boundary (with $M_B = -22.3$ in our assumed cosmology of $H_0 = 70\mathrm{kms^{-1}Mpc^{-1}}$, $\Omega_{\rm M} = 0.3$, $\Omega_\Lambda = 0.7$) would have a 5μm luminosity of $\lg(L_{5\mu m}/\mathrm{WHz^{-1}}) \approx 23.6$. Thus most of our spectroscopic targets have mid-IR luminosities corresponding to low-to-moderate luminosity quasars (Table 1).

4. The host galaxies

Fig. 2 shows a composite spectrum made from five of the quasar-2, spectra (all taken with the Double Spectrograph of the Palomar 200″). Balmer absorption is clearly visible, indicating a significant A-star population, and thus star formation within the past $\sim 10^8$yr.

5. Discussion

Our spectroscopy has allowed us to confirm the result of Paper 1, namely, that at mid-IR luminosities corresponding to low-luminosity quasars, we find an $\approx 1 : 1$ ratio of type-2 to type-1 AGN. Most of our mid-IR selected obscured AGN seem to have unobscured narrow-line regions. Two of our objects are not classifiable as AGN based on their optical spectra. One shows no emission lines, and the other has a starburst-like spectrum. Both these objects have extremely red mid-IR spectra, so may represent either very deeply buried AGN with no emission able to escape to photoionize the narrow-line region, or starburst galaxies with extremely warm dust. Combining our spectroscopic redshifts with the photometric redshifts for the remainder of the sample of Paper 1 shows that the median redshift of our obscured AGN (0.46) is lower than that of the unobscured population (0.69). Whether this is real, or a consequence of redshift-dependent selection effects remains to be determined. If real, it would be consistent with a luminosity-dependent obscured AGN fraction, and with the peak of obscured AGN activity being at lower redshift, as determined from X-ray surveys (e.g. Cowie et al. 2003). Urry & Triester (2004), whose multiwaveband sample of AGN consists of predominately lower-luminosity objects, find a 3:1 ratio of type-2 to type-1 AGN, pointing to a luminosity-dependence of the obscured AGN fraction. However, we expect the effectiveness of mid-IR selection of AGN to decrease with redshift as the host galaxy light becomes redshifted into the IRAC bands. Modelling of mid-IR SEDs by Sajina, Lacy & Scott (2004), suggests that we should still be able to pick out obscured AGN up to $z \sim 2$ using the IRAC bands alone, however, the fact that our highest redshift AGN at $z = 1.34$ shows a broad line in the optical suggests that we may be losing a significant fraction of the more obscured objects at $z \sim 1$.

Table 1. Results of optical spectroscopy

Object	z	$S^*_{8\mu m}$ (mJy)	$\lg(L_{5\mu m}$ (WHz^{-1}))	Nature of optical spectrum
SSTXFLS J171106.8+590436	0.462	1.38	23.71	high-ionization, narrow lines
SSTXFLS J171115.2+594906	0.587	5.09	24.30	starburst spectrum
SSTXFLS J171147.4+585839	0.800	1.83	24.30	high-ionization, narrow lines
SSTXFLS J171313.9+603146	0.105	4.65	22.90	high-ionization, narrow lines
SSTXFLS J171324.3+585549	0.609	1.30	23.85	high-ionization, narrow lines
SSTXFLS J171804.6+602705	0.43?	1.18	23.71	single narrow emission line
SSTXFLS J171831.6+595317	0.700	1.22	24.27	high-ionization, narrow lines
SSTXFLS J171930.9+594751	0.358	1.57	23.56	high-ionization, narrow lines
SSTXFLS J172050.4+591511	?	3.63	-	featureless red continuum
SSTXFLS J172123.1+601214	0.325	3.71	23.89	high-ionization, narrow lines
SSTXFLS J172328.4+592947	1.34?	1.69	25.12	single broad emission line
SSTXFLS J172458.3+591545	0.494	1.18	23.85	high-ionization, narrow lines

* these values supercede those in Paper 1.

Further progress may depend on being able to include MIPS 24μm fluxes in the AGN selection criterion.

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