The AGN Power in Type 2 ULIRGs with a High [OIII] Luminosity Observed by *Suzaku* and *XMM-Newton*

Yoshitaka Hirata[1], Yuichi Terashima[1], Naohisa Anabuki[2], Takao Nakagawa[3] and Hisamitsu Awaki[1]

[1] Ehime University, Matsuyama, Ehime 790-8577, Japan
[2] Osaka University, Toyonaka, Osaka 590-0043, Japan
[3] ISAS/JAXA, Sagamihara, Kanagawa 229-8510, Japan
E-mail(YH): hirata@astro.phys.sci.ehime-u.ac.jp

Abstract

We present results from observations of three ultraluminous infrared galaxies(ULIRGs) with *Suzaku* and *XMM-Newton*. Their optical emission lines are classified as seyfert 2 and extinction-corrected [OIII]λ5007 line luminosities are $(3.2–61)\times10^{43}$ erg s^{-1}, which are in the range for quasars. Their X-ray spectra are explained by a combination of unabsorbed and absorbed power-law components. Fe Kα lines are not detected. The absorption-corrected 2-10 keV luminosities $L_{2-10\mathrm{keV}}$ are in the range of $(3.3–24)\times10^{42}$ erg s^{-1}. These results indicate that these objects are Compton-thin AGNs with Seyfert class luminosity. We compare the far infrared (FIR) luminosities L_{FIR} with the bolometric luminosities of the AGNs and find that the contribution of AGNs to L_{FIR} is at most a few tens of percent.

Key words: ULIRG, active galactic nuclei, starburst galaxy

1. Introduction

Ultraluminous infrared galaxies (ULIRGs) are objects emitting the bulk of their energy at the infrared band with $L_{8-1000\mu m} \geq 10^{12}\ L_\odot$. Primary energy sources of ULIRGs are still under debate and possible candidates are active galactic nuclei (AGNs) and/or starbursts.

A fraction of type 2 AGNs decreases with increasing X-ray luminosity (Ueda et al. 2003). This trend may indicate that the shape of obscuring matter depends on luminosity. An alternative explanation is that many type 2 quasars are obscured by Compton-thick material. Fiore et al. (2009) suggest that many mid-infrared-selected objects are Compton-thick quasars. Therefore, ULIRGs are good candidates of Compton-thick quasars. They should be type 2 quasars if their infrared luminosities are predominantly powered by an AGN.

2. Sample and Results

We selected type 2 quasar candidates from the IRAS 1 Jy sample (Veilleux et al. 1999) using the following criteria, (1) classified as Seyfert 2 using optical emission line ratios, (2) extinction-corrected [OIII]λ5007 luminosity $L_{\mathrm{[OIII]}} > 10^{42}$ erg s^{-1}, which is in the range for quasars (Zakamska et al. 2003), and (3) high extinction-corrected [OIII]λ5007 flux. We selected three type 2 ULIRGs IRAS 11223–1244, IRAS 05024–1941, and IRAS 13443+0802. Their $L_{8-1000\mu m}$ and $L_{\mathrm{[OIII]}}$ are $(3.3–17)\times10^{12}\ L_\odot$ and $(3.2–61)\times10^{43}$ erg s^{-1}, respectively, which are in the range for type 2 quasars. IRAS 11223−1244 was observed with *Suzaku* on 2006 November 25-26. IRAS 05024−1941 and IRAS 13443+0802 were observed with *XMM-Newton* on 2007 February 7-8 and 2006 December 23, respectively.

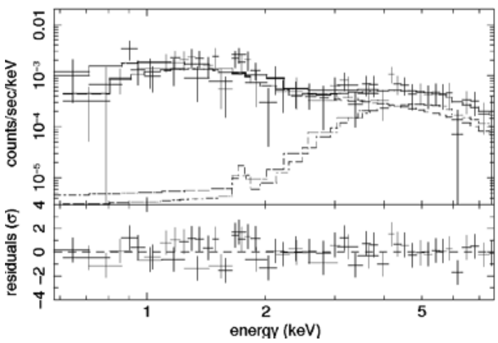

Fig. 1. Suzaku XIS spectra of IRAS 11223–1244.

We fitted spectra of these three ULIRGs with a partial-covering model consisting of unabsorbed and absorbed power-law components, as is often observed in Seyfert 2 galaxies (e.g., Turner et al 1997, Dadina 2008). We assumed that the slope of the two power laws are same. All the components were assumed to be modified by the Galactic absorption (Kalberla et al. 2005). Many Seyfert

This document is provided by JAXA.

2 galaxies show a strong Fe Kα line around 6.4 keV in their spectra. If the nucleus is surrounded by compton-thick gas, an equivalent width EW of the Fe Kα line is above about 1 keV (e.g., Bassani et al. 1999). Therefore we added a gaussian component to the model and searched for Fe Kα emission. We fixed the center energy at 6.4 keV and the line width at $\sigma = 10$ eV. The small improvement of χ^2 ($\Delta\chi^2 \leq 0.3$) for a change in d.o.f. of 1 suggests that the additional gaussian component was not significant.

The slope of the power law $\Gamma = 1.48$–1.80 is in the range seen in Seyfert 2 galaxies (1.47–2.59; Risaliti 2002) and Palomar-Green (PG) quasars (1.2–1.9; Piconcelli et al. 2005). The observed column densities $N_{\rm H} \leq 5\times10^{23}$ cm^{-2} and the upper limits on the EW of the Fe Kα line $\leq$ 630 eV indicate that the sources are absorbed by Compton-thin material. The absorption-corrected X-ray luminosities in the 2-10 keV band $L_{2-10\rm keV} = (3.3$–$24)\times10^{42}$ erg s^{-1} are Seyfert class and these objects are not type 2 quasars, whose luminosities are $\geq 10^{44}$ erg s^{-1} in the X-ray band. These results indicate that these three ULIRGs are Seyfert 2 galaxies obscured by Compton-thin material.

3. Discussion

In order to constrain the primary energy source of the far infrared (FIR) emission in these ULIRGs, we compared their $L_{2-10\rm keV}$ and FIR luminosities $L_{\rm FIR}$ with those of other ULIRGs, Seyferts, and HII galaxies (Fig 2). A sample of ULIRGs has been selected from the IRAS 1 Jy sample by Veilleux et al. (1999). Seyferts and HII galaxies are compiled from Heckman et al. (2005) and Ho et al. (1997), respectively. We collected X-ray data from the literature for these samples. FIR flux densities at 60 and 100 μm were taken from NASA/IPAC extragalactic database and FIR fluxes in the 40–120 μm band were calculated using an equation of Helou et al. (1985) from the flux densities.

The $L_{2-10\rm keV}/L_{\rm FIR}$ ratios of the three ULIRGs are lower than Seyfert galaxies. Possible explanations are (1) we underestimated the AGN luminosities of the ULIRGs and/or (2) contribution from starburst is large. In order to estimate the contribution of the AGN to the infrared (IR) luminosity, we compared the IR luminosities $L_{8-1000\mu m}$ and bolometric luminosities $L_{\rm bol,AGN}$ of the AGN component in the three ULIRGs. We used a bolometric correction factor $\kappa = 20$ (Vasudevan & Fabian 2007) in calculations of $L_{\rm bol,AGN}$ from $L_{2-10\rm keV}$. In addition, since it is suggested that X-rays tend to underestimate the luminosity of AGNs in ULIRGs by an order of magnitude compared to other indicators of AGN luminosities (e.g., Imanishi & Terashima 2004), we introduced a correction of another factor of 10 in the calculations of $L_{\rm bol,AGN}$. Thus we calculated the bolometric luminosities using the equation $L_{\rm bol,AGN} = L_{2-10\rm keV}\times20\times10$. The $L_{\rm bol,AGN}/L_{8-1000\mu\rm m}$ ratios of these three ULIRGs are 0.071–0.30. These values indicate that if all photons radiated from the AGN are converted to IR, the contribution of the AGN to $L_{8-1000\mu\rm m}$ is estimated to be at most a few tens of %. Therefore, the contribution from starbursts is likely to be very large.

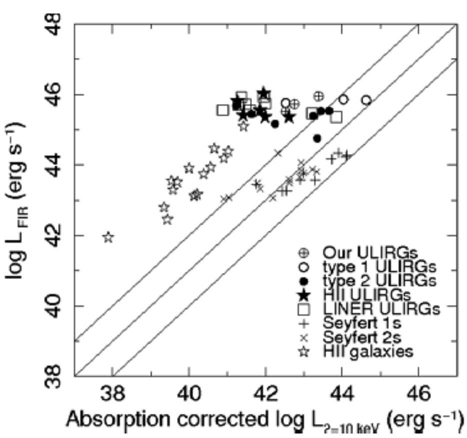

Fig. 2. Correlation between log of absorption corrected 2–10 keV luminosity and far infrared luminosity.

The $L_{2-10\rm keV}/L_{\rm [OIII]}$ ratios of the ULIRGs (0.040–0.10) are lower than those for Compton-thin Seyferts (e,g., 1-100; Bassani et al. 1999). Since these ULIRGs show a very large Balmer decrement Hα/Hβ = 14–50, there can be large uncertainties in the extinction-corrected $L_{\rm [OIII]}$. In addition, as mentioned above, we might underestimate the AGN power by a factor of 10. If these two factors are taken into account, the ratios are in the range for Compton-thin Seyferts.

References

Bassani L. et al. 1999 ApJS., 121, 473
Dadina M. 2008 A&A., 485, 417
Fiore F. et al. 2009 ApJ., 693, 447
Heckman T. M. et al. 2005 ApJ., 634, 161
Helou G. et al. 1985 ApJ., 298, 7
Ho L. C. et al. 1997 ApJS., 112, 315
Imanishi M. & Terashima Y. 2004 AJ., 127, 758
Kalberla P. M. et al. 2005 A&A., 440, 775
Piconcelli E. et al. 2005 A&A., 432, 15
Risaliti G. 2002 A&A., 386, 379
Turner T. J. et al. 1997 ApJ., 113, 23
Ueda Y. et al. 2003 ApJ., 598, 886
Vasudevan R. V. & Fabian A. C. 2007 MNRAS., 381, 1235
Veilleux S. et al. 1999 ApJ., 522, 113
Zekamska N. L. et al. 2003 ApJ., 126, 2125

This document is provided by JAXA.