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The Spectral Energy Distributions of Different Types of Seyfert Galaxies

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Abstract We calculated the average spectral energy distributions (SEDs) for Seyfert 1 galaxies (S1s) and two types of Seyfert 2 galaxies (S2s with or without polarized broad-line regions, i.e. HBLRs and Non-HBLRs). We found that compared with other Seyfet galaxies, the Non-HBLRs show an extremely brighter feature towards the far infrared band, which is believed to be affected by the circumnuclear starburst components. The energy in this band seems to dominate their bolometric luminosities. A weaker hard X-ray emission was also found in these Non-HBLRs, which is believed to be the indicator of a weaker nuclear power. So in the case of Non-HBLRs, any use of bolometric luminosities to represent the active galactic nuclei (AGN) power is possibly misleading.

Key words: galaxies: active — galaxies: Seyfert — infrared: galaxies — X-rays: galaxies

1 INTRODUCTION

According to an unification model of active galactic nuclei (Antonucci 1993), Seyfert 1 and Seyfert 2 galaxies are thought to be intrinsically the same. Because of the existence of a dust torus, the nuclei and broad line region of Seyfert galaxies may not be seen directly when taking an edge-on sight. Therefore, the differences in Seyfert 1s and Seyfert 2s can be understood according to the orientation.

However, polarization observations have recently revealed that only about half of the Seyfert 2s were found to display broad-line components in their spectra (Young et al. 1996; Moran et al. 2000; Tran 2001). The Seyfert 2s with hidden broad line regions (HBLRs) and without hidden broad line regions (Non-HBLRs) are now well studied with the available data from X-ray to radio bands (Heisler et al. 1997; Gu & Huang 2002; Tran 2001, 2003; Deluit 2004). The results suggest that a true type of Seyfert 2s may exist which intrinsically have no broad-line regions because of a weaker central power. Nicastro, Martocchia & Matt (2003) found that the HBLRs probably have a higher accretion rate than Non-HBLRs.

In this paper we want to compare the properties of the SEDs among different types of Seyfert galaxies, especially between HBLRs and Non-HBLRs, and to investigate their nuclear activities which may be reflected in the SEDs. We will describe the sample and data in Sect. 2, give the main results in Sect. 3, further discussions in Sect. 4, and conclusions in Sect. 5. A cosmology with H_0=75 km s^{-1} Mpc^{-1}, $q_0 = 0.5$ is adopted throughout this paper.

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2 THE SAMPLE AND DATA

The sample we collected for the average spectra calculation is composed of 16 Seyfert 1s , 12 HBLRs, and 11 Non-HBLRs (Woo & Urry 2002; Gu & Huang 2002; Tran 2003) with available data from X-ray to radio band(George et al. 1998; Bassani et al.1999; Turner & Pounds 1989; McQuade et al. 1995; Storchi-Bergmann et al. 1995) Some of the data are also from the NED database.

3 RESULTS

3.1 Spectral energy distributions and comparisons

We show the mean SEDs of different Seyfer galaxies in Fig.1(a), normalized at 1.25 μm. Different properties can be seen from the SEDs.

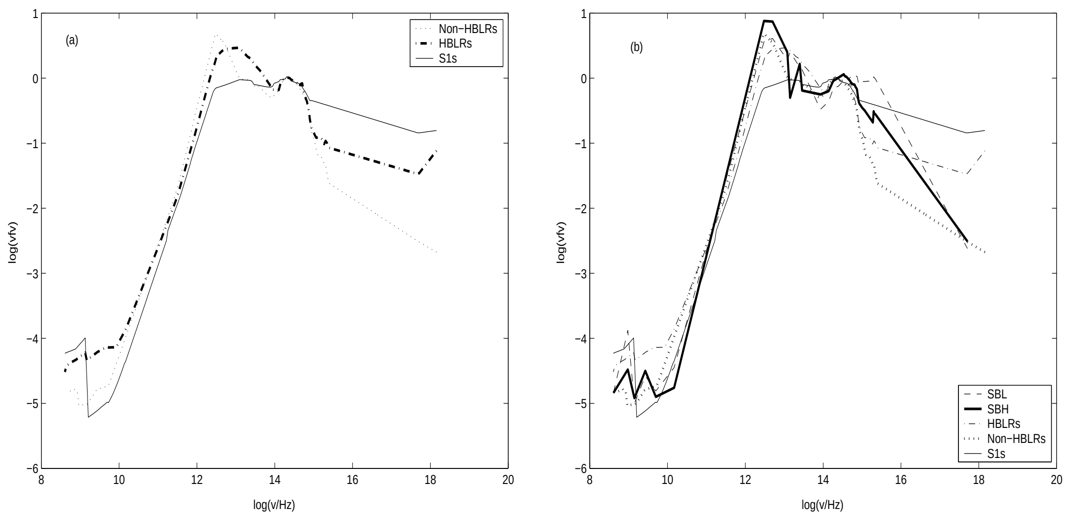

Fig. 1 (a)The average SEDs for S1s (solid line), HBLRs (dash-dot line) and Non-HBLRs (dotted line) normalized at 1.25 μm. (b)The SED comparison between Seyfert galaxies and starburst galaxies (Schmitt et al.1997) normalized at 0.7 μm.The starburst galaxies were divided into low reddening starbursts (SBL,dashed line) and high reddening starbursts (SBH, heavy solid line) according to different E(B-V).

Non-HBLRs seem much weaker in hard X-ray band when compared with the other classes of objects. However the limited data available in X-ray and radio bands must be taken into account in the interpretation of the results. The difference in Compton thickness is another factor that is needed to be considered. So we need to take care when discussing the different SEDs.

In the SED of S1s, the UV/optical and infrared emission are comparable. However in the case of HBLRs, the infrared emission is relatively stronger than the UV/optical band, which may be caused by a strong obscuration and re-radiation from the thick circumnuclear dust in HBLRs.

However, the infrared slopes for S1s and HBLRs are all the same, but the Non-HBLRs show a steeper increase feature towards the far infrared band. This result is consistent with

Table 1 The statistic results of the distributions above. Col. (1)–(6) give the number of each type of sources and the mean value in logarithmic form. The luminosities in unit of erg s^{-1}, and statistic errors are also listed. (A)-all sources,(B)-Compton thin sources.

	S1		HBLR		Non-HBLR	
	number (1)	means (2)	number (3)	means (4)	number (5)	means (6)
$L_{\rm EDD}$	24	45.48±0.54	18	45.63±0.44	17	45.55±0.53
$L_{\rm bol}$	24	44.65±0.49	31	44.26±0.38	22	43.91±0.52
$L_{2-10\,{\rm keV}}$(A)	17	43.13±0.80	24	42.31±1.04	12	41.15±1.07
$L_{2-10\,{\rm keV}}$(B)	17	43.13±0.80	12	42.97±0.56	6	41.43±1.09

Table 2 The K-S test results for different Seyfert galaxies,(A)-all sources,(B)-Compton thin sources.

	K-S Pnull		
	S1 + HBLR (1)	HBLR + NonHBLR (2)	S1 + NonHBLR (3)
$N_{\rm H}$	0.0128	0.9686	0.016
$L_{\rm EDD}$	0.2032	0.8779	0.4529
$L_{\rm bol}$	0.0059	0.2822	0.0009
$L_{2-10\,{\rm keV}}$(A)	0.032	0.0694	0.0003
$L_{2-10\,{\rm keV}}$(B)	0.283	0.0571	0.0112

the conclusion in Tran (2001, 2003), who suggested the HBLRs and Non-HBLRs can be distinguished by the IRAS color (i.e. $f_{25\mu{\rm m}}/f_{60\mu{\rm m}}$). In addition the strong far infrared emission in Non-HBLRs seems to dominate the bolometric luminosities. This fact suggests that the star formation may affect the SED of the Non-HBLR and that the energy emission from this activity largely contributes to the bolometric luminosity (Imanishi 2004; Mouri & Taniguchi 1992; Mouri & Taniguchi 2004).

In Fig.1(b) we compare the SEDs of Seyfert galaxies and of starburst galaxies. The average spectra of starburst galaxies were calculated by Schmitt et al. (1997). The Non-HBLRs do show a similar feature in the infrared band as the starburst galaxies, or even steeper when compared to the low reddening starbursts.

3.2 Bolometric luminosities and Nuclear Properties

Here we further discuss the features of Seyferts which are indicated by the mean SEDs and try to understand the intrinsic differences of the nuclei. A large sample of Seyfert galaxies is collected, combining the Seyfert 2 sources from Tran (2003) and Gu & Huang (2002), and the Seyfert 1 sources from Woo & Urry (2002). In Fig.2 we compare the circumnuclear absorbing column densities ($N_{\rm H}$) and luminosities (i.e. Eddington luminosities, bolometric luminosities, and hard X-ray 2–10 keV luminosities) with available data (Basanni et al. 1999; George et al. 1998; Turner & Pounds 1989; Tran 2003), and in Table 1 and 2 we give the statistical results.

The $N_{\rm H}$ distributions are similar between HBLRs and Non-HBLRs, and no significant differences in Eddington luminosity ($L_{\rm Edd}$) distributions are found. So we can exclude differences in circumnuclear obscuring material and central black hole masses. Also, the bolometric luminosity ($L_{\rm bol}$) distributions are similar between HBLRs and Non-HBLRs. However considering

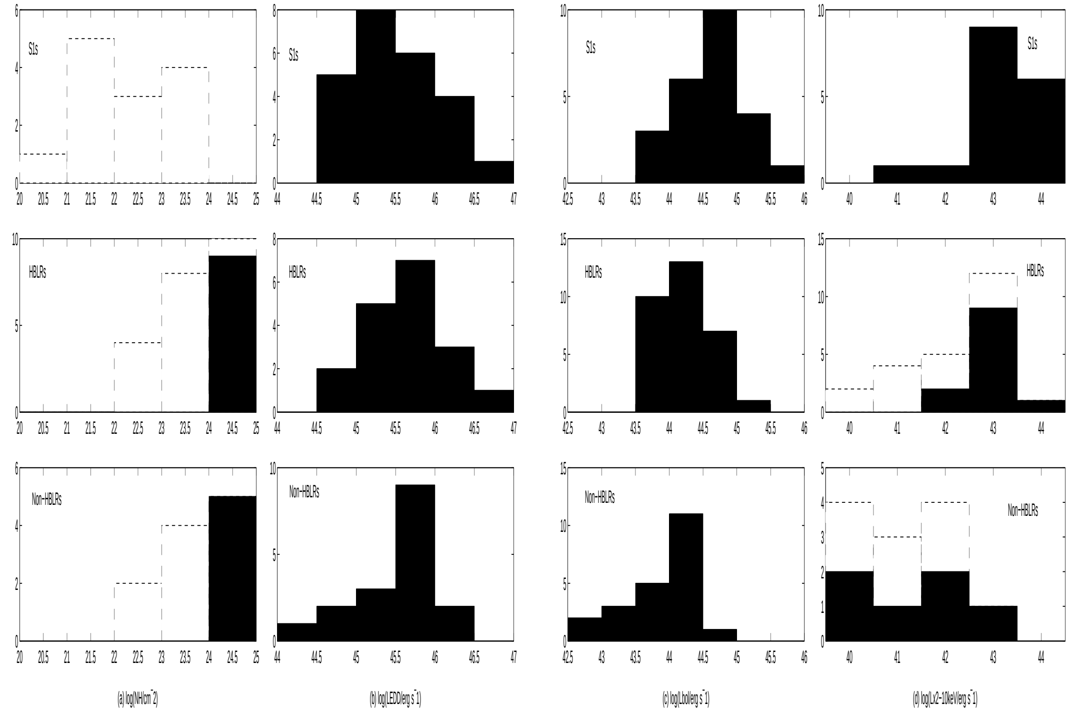

Fig. 2 (a), (b), (c), (d) give the distributions of $N_{\rm H}$, Eddington luminosities ($L_{\rm Edd}$), bolometric luminosities ($L_{\rm bol}$), and hard X-ray 2–10 keV luminosities ($L_{2-10\,\rm keV}$). We calculate the black hole masses with available velocity dispersions from HYPERCAT data center, using the relation in Tremaine et al. (2002). For (a), the black part represents the Compton thick sources, while the white part represents the Compton thin sources. For (d), the black part represents the contributions from the Compton thin sources, while the white part represents the contributions from the Compton thick sources.

that the bolometric luminosities of Non-HBLRs are dominated by the far infrared emission which is affected significantly by the star formation activities, the central nuclear emission may be intrinsically different between HBLRs and Non-HBLRs. The hard X-ray 2–10 keV luminosity ($L_{2-10\,\rm keV}$) distribution for Compton thin HBLRs is similar to that of S1s, while the Compton thin Non-HBLRs are significant different and distribute in a lower energy range. This fact gives strong evidence that the nuclear power in Non-HBLRs may be intrinsically weak, as discussed by Tran (2003).

In Fig. 3 we plot $L_{2-10\,\rm keV}$ versus the $L_{\rm bol}$ for sources belonging to the samples mentioned above.

A relation is seen in S1s between the $L_{2-10\,keV}$ and the bolometric luminosities, except several scattered points (MKN 841, NGC 6814, and NGC 7469). The Compton thin HBLRs seem to follow S1s' relation. The Non-HBLRs have the smallest X-ray luminosities and seem to have no agreement between X-ray and total luminosities no matter Compton thick or Compton thin. In addition, if the total nuclear emission and the hard X-ray emission follow the same correction as S1s and Compton thin HBLRs, the bolometric luminosities of Non-HBLRs obviously much lager than the value predicted by their 2–10 keV luminosities. This fact gives further evidence that the nuclear emissions in Non-HBLRs are intrinsically weak and the bolometric luminosities are dominated by the starburst activities.

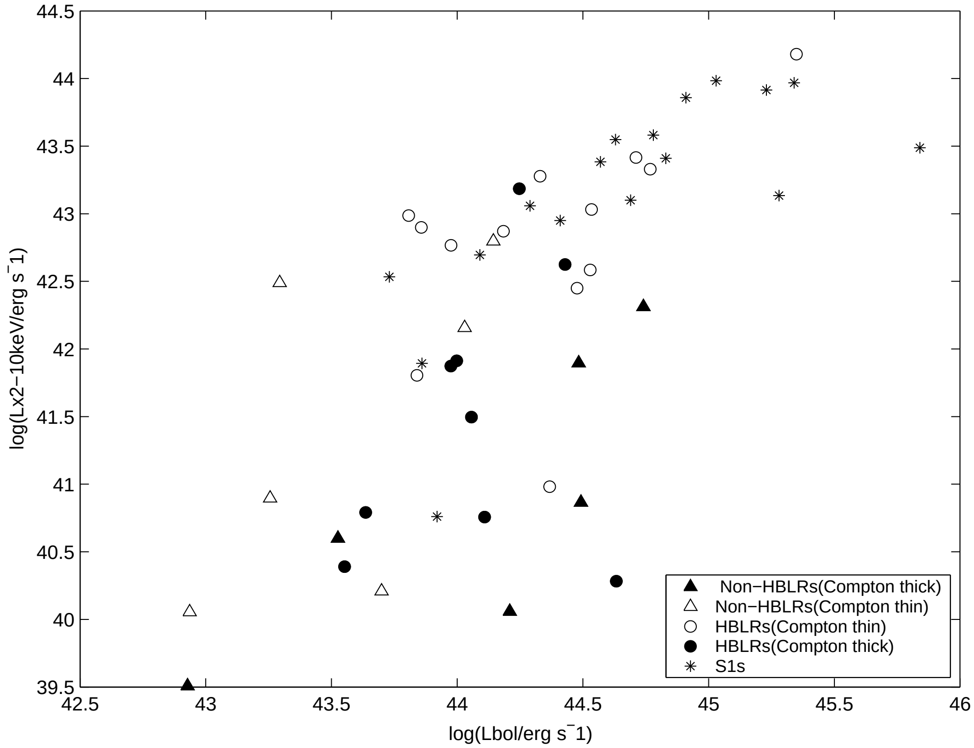

Fig. 3 L2–10 keV and Lbol of S1s (star symbol) HBLRs (circle) and Non-HBLRs (triangle). The Compton thick sources are plotted as filled symbols, while the Compton thin ones are plotted as open symbols.

4 DISCUSSION

Circumnuclear star formation activities can always be found in Seyfert galaxies (Wilson 1991; Mouri & Taniguchi 1992; Heckman et al. 1997; Mouri & Taniguchi 2004). For powerful nuclei, the strong nuclear emissions can dominate the SEDs, but if the nuclear emissions are intrinsically weak, energy contributions from other parts, such as starburst activities, may become important or even dominated.

Other things needed to point out are the problems with the sample and data. The sources and data used to calculate the mean SEDs are still limited and data in soft X-ray, millimeter and radio bands are needed to add.

After all, an orientation-based unification model alone seems difficult to explain all observed feature of AGNs. A more reliable model should include not only orientation but also other physical parameters which indicate the intrinsically differences of AGNs. A model with the effects of host galaxies and evolution is also needed to study the relation between starburst activities and galactic nuclei.

5 CONCLUSION

In this paper, we collected multi-wavelength data for a sample of 39 Seyfert galaxies, which include 16 S1s 12 HBLRs and 11 Non-HBLRs, and calculated the average spectral energy distributions for each type of sources. Distinct differences are displayed in the mean SEDs. Most of the Non-HBLRs' bolometric luminosities are dominated by the far infrared emission, while their hard X-ray emissions are weaker compared with S1s and HBLRs. As no obvious statistic $N_{\rm H}$ difference is found in large complete samples, this fact may imply that a less powerful central nuclear engine is present in Non-HBLRs. Therefore, the bolometric luminosities of Non-HBLRs are affected significantly by the star formation activities and no longer indicate the true AGN power in these sources.

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