**Annuaire de l'Universite de Sofia "St. Kliment Ohridski", Faculte de Physique, 102, 2009**

# INVESTIGATION OF THE TWO TYPES UNABSORBED SEYFERT 2 GALAXIES

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*Георги П. Петров*. ИЗСЛЕДВАНЕ НА ДВАТА ТИПА СИЙФЪРТ-2 ГАЛАКТИКИ С НИСКО ПОГЛЪЩАНЕ В РЕНТГЕНОВИЯ ДИАПАЗОН НА СПЕКТЪРА

Събрали сме извадка от 27 близки Сийфърт-2 галактики с ниско поглъщане в рентгеновия диапазон на спектъра. Техните колонкови плътности са $N_{\rm H} < 10^{22}$ cm$^{-2}$. Сийфърт-2 галактиките с ниско поглъщане в рентгеновия диапазон са разделени на два подтипа: галактики, които притежават скрита област на широките крила на линиите; и галактики без такава област. Ние изследвахме галактиките от нашата извадка за наличие на скрита област на широките крила на линиите, използвайки единтоновите отношения $L_{\rm Bol} / L_{\rm Edd}$. Съществува критична стойност на единтоновото отношение, $10^{-3}$, под която не се наблюдава скрита област на широките крила на линиите. Също така, когато това отношение е $\geq$ 0,2–3, широките крила на линиите отново липсват. Установихме, че само 4 обекта от нашата извадка притежават скрита област на широките крила на линиите. Останалите обекти не показват наличие на такава област. Също определихме, че 12 обекта със сигурност не притежават скрита област на широките крила на линиите. Получили сме отношението $(N_{\rm ph} / N_{\rm ion})_{h\nu > 55\ {\rm eV}}$ за обектите от нашата извадка – броят на фотоните, проследени от линията [OIII] λ5007Å, $N_{\rm ph}$, отнесен към броя на йонизиращите фотони, $N_{\rm ion}$, излъчени от централния източник, с енергии $h\nu > 55$ eV. В анизотропния случай отношението $(N_{\rm ph} / N_{\rm ion})_{h\nu > 55\ {\rm eV}}$ е значително по-голямо от 1 и тези обекти притежават скрит централен източник. Съобразно нашите резултати обектите от извадката, които са със скрита област на широките крила на линиите, притежават такава анизотропия и съответно имат скрит централен източник на лъчение.

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We have compiled a sample of 27 nearby unabsorbed Seyfert 2 type galaxies. These objects are X–ray unabsorbed and their measured column densities are $N_H < 10^{22}$ cm$^{-2}$. The Unabsorbed Seyfert 2 galaxies are divided in two types: unabsorbed Seyfert 2 galaxies with and without hidden broad line region (HBLR). We have investigated the unabsorbed Seyfert 2 galaxies for presence of a HBLR using calculated Eddington ratios $L_{Bol} / L_{Edd}$ . There is a critical value of the Eddington ratio, $10^{-3}$, below which there is no HBLR. When this ratio is $\geq$ 0.2–3 the broad lines also disappear. We found that only 4 objects of our sample have a HBLR. For the rest of the sample there is no evidence for existence of a HBLR. We determined that 12 objects certainly don't have a HBLR. At the same time, we have derived the ratio $(N_{ph} / N_{ion})_{h\nu > 55\ eV}$ of the number of photons traced by the [OIII] λ5007Å emission line ($N_{ph}$) to the number of high ionizing photons $N_{ion}$ emitted by the central AGN source with $h\nu > 55$ eV for all sample objects. In the anisotropic case the ratio $(N_{ph} / N_{ion})_{h\nu > 55\ eV}$ is larger than 1 and these objects possess a hidden AGN source. From the results can be inferred that unabsorbed Seyfert 2 galaxies with HBLR show an anisotropy and they have hidden central source.

***Keywords:*** galaxies: active; X-rays: galaxies; galaxies: Seyfert; polarization
***PACS numbers:*** 98.54.-h; 98.54.Cm; 98.62.Js

## 1. INTRODUCTION

The standard theory of active galaxies is based on the idea of an accretion disk around a massive black hole. This theory predicts the presence of a hard X-ray continuum from a central engine, that is strong enough to photoionize the Broad Line Region (BLR – closer to the source) and the Narrow Line Region (NLR – at < 100 pc from the nuclear engine).

Seyfert galaxies are divided into types 1 and 2 in the Unified model which is orientation-based unification scheme. According to this model, the two types Seyferts are actually the same objects but they differ only in their orientation. Seyfert 2 type galaxies possess a BLR but it is obscured by a molecular torus and because of this it is unobservable.

In fact, there are some exceptions from this Unified model. Some Seyfert 2 type galaxies don't harbour a BLR, so they are the "true" Seyfert 2 galaxies – without hidden broad line region (HBLR) [1, 2].

Not all Seyfert 2 galaxies have a BLR in polarized light, and not all Seyfert 2 galaxies have column densities higher than $10^{22}$ cm$^{-2}$. Normally the column density of neutral hydrogen $N_H$ for X–ray radiation in type 2 Seyferts is significantly higher than this in type 1 objects, because of the torus around

the nucleus, which is on the line of sight. However, there are some Seyfert 2 galaxies, which are X–ray unabsorbed and their measured column densities are $N_H < 10^{22}$ cm$^{-2}$ [3].

In this paper we have studied a sample of 27 nearby unabsorbed Seyfert 2 type galaxies for a presence of a HBLR, using the Eddington ratio $L_{Bol} / L_{Edd}$ as a criterion.

We have also calculated the ratio $(N_{ph} / N_{ion})_{h\nu > 55\ eV}$ for the two types unabsorbed Seyfert 2 galaxies (with and without HBLR) to probe them for anisotropy and hidden central engine.

## 2. DATA AND RESULTS

Our sample contains 27 nearby Seyfert galaxies and most of them are classified by NED as Seyfert 2 type, but others as type 1.8 – 1.9. For the sake of simplicity, we generally call them Seyfert 2. All objects have $N_H < 10^{22}$ cm$^{-2}$. In this paper we adopt the cosmological constant $H_0 = 75$ km s$^{-1}$ Mpc$^{-1}$.

We have used from Wang & Zhang [4] the empirical relation $M_{BH} - \sigma$ to estimate the mass of the central massive black hole:

$M_{BH} = 1.35 \times 10^8\ M_\odot\ (\sigma / 200\ \text{km s}^{-1})^{4.02}$ ,

with $\sigma$ being the central stellar velocity dispersion of the galaxy,

and the Eddington ratio:

$$(L_{Bol} / L_{Edd}) = 0.1 \left( \frac{L_{Bol}}{1.4\times10^{44}\ \text{erg.s}^{-1}} \right) \left( \frac{M_{BH}}{10^7 M_\odot} \right)^{-1} ,$$

where $L_{Bol} = 30\ L_{2-10keV}$ is the bolometric luminosity [5]; see Table 1.

The unabsorbed Seyfert 2 galaxies are divided into two types: unabsorbed Seyfert 2 galaxies with and without HBLR. There is a critical value of the Eddington ratio $10^{-3}$ (see Fig.1), below which there is no HBLR [6]. When the Eddington ratio is $\geq 0.2–3$, the broad lines also disappear. It is possible for the objects without HBLR to occupy the areas below and above the Nicastro's boundary. A possible reason for this fact is the presence of two sub-types unabsorbed galaxies without HBLR: one with lower black hole masses and one with more massive black holes (see Table 1). This idea is mentioned in Wang & Zhang [4].

We know that the normalized accretion rate is $\dot{m} \propto (L_{Bol}/L_{Edd})$ [7]. Thus, it is obvious that the unabsorbed galaxies without HBLR and with more massive black holes in their centres have lower accretion rates than the other

unabsorbed Seyfert 2 galaxies. These objects are probably at the final stage of the evolution of Seyfert 2 galaxies, when the torus is depleted and the accretion rates are very low.

Our sample contains 4 objects which have observed polarized broad lines (IRAS F01475-0740, NGC 2992, NGC 5929, NGC 5995) and 4, which are shown to not have (MRK 334, NGC 3660, NGC 4501, NGC 7590) – see Shu et al. [8]. There are 8 objects of the rest of the sample which are below the critical value of the Eddington ratio, thus they also don't harbour a HBLR (see Fig.1).

On Fig.2 it is visible that unabsorbed Seyfert 2 galaxies with HBLR (marked with squares) occupy only the upper right corner of the graphic. Using the same diagnostic diagram Tran [2] showed the separation between objects with and without HBLR for all species (Compton thick and Compton thin, but mainly for Compton thick) of Seyfert 2 objects. Here we have the same separation only for the unabsorbed Seyfert 2 galaxies that have Compton thin nature.

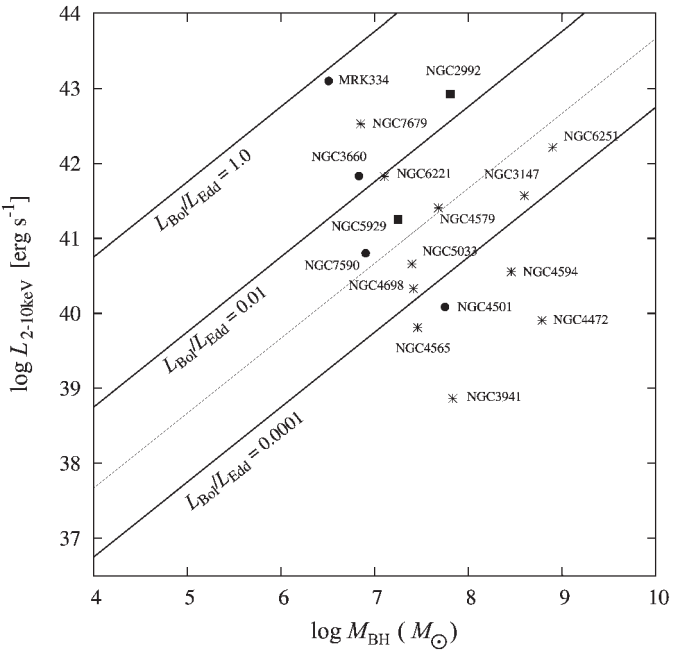


Fig. 1. The relation between the luminosity $L_{2-10keV}$ and the mass of the central massive black hole is shown. The thin line on the figure indicates the critical value of the Eddington ratio – $10^3$. The objects, which have polarized broad lines, are marked with squares; these without polarized broad lines are shown with circles; asterisks denote the galaxies that are unspecified from observations about existence of a HBLR

**Table 1.** Observed and calculated data for 27 unabsorbed Seyfert 2 galaxies

| Name | $z$ | log $N_H$ | Γ | $F_{2-10keV}$ | $F_{[OIII]}$ | σ | $M_{BH}$ | log($L_{Bol}$/ $L_{Edd}$) | $N_{ph}/N_{ion}$ |
|---|---|---|---|---|---|---|---|---|---|
| MRK 273x | 0.45800 | 21.15 | 1.66 | 0.01 | 0.00014 | – | – | – | 0.15 |
| MRK 334 | 0.02195 | 20.64 | 2.00 | 1.366 | 0.2 | 79 * | 0.3 | –0.08 | – |
| IRAS F01475–0740 | 0.01767 | 21.59 | 2.06 | 0.075 | 0.0625 | – | – | – | 2.52 |
| IRAS 20051–1117 | 0.03150 | < 21.60 | 1.92 | 0.24 | 0.0152 | – | – | – | 0.31 |
| ESO 540–G001 | 0.02685 | 20.28 | 1.99 | 0.08 | 0.024 | – | – | – | 1.15 |
| CGCG 303–017 | 0.03713 | 21.56 | 1.71 | 0.215 | 0.0126 | – | – | – | 0.56 |
| CGCG 551–008 | 0.02362 | < 20.60 | 2.09 | 0.031 | 0.0047 | – | – | – | 0.41 |
| MCG 03–05–007 | 0.01993 | < 20.48 | 1.85 | 0.069 | 0.0102 | – | – | – | 0.90 |
| UGC 03134 | 0.02871 | 21.23 | 1.34 | 0.019 | 0.0065 | – | – | – | 8.24 |
| IC 1631 | 0.03084 | < 21.50 | 2.10 | 1.00 | 0.052 | – | – | – | 0.14 |
| NGC 2992 | 0.00771 | 21.95 | 1.70 | 7.4 | 0.680 | 166.1 | 6.4 | –1.55 | 0.90 |
| NGC 3147 | 0.00941 | < 20.46 | 1.94 | 0.22 | 0.009 | 261.3 | 39.5 | –3.70 | 0.19 |
| NGC 3660 | 0.01229 | 20.26 | 1.83 | 0.236 | 0.0593 | 95 * | 0.7 | –1.67 | 1.64 |
| NGC 3941 | 0.00310 | ≤ 21.00 | 2.1 | 0.004 | 0.00329 | 168.7 | 6.8 | –5.64 | 2.17 |
| NGC 4472 | 0.00333 | 21.48 | 1.61 | 0.038 | 0.0003 | 291.1 | 61.0 | –5.55 | 0.10 |
| NGC 4501 | 0.00761 | 21.30 | 1.5 | 0.011 | 0.0054 | 160.9 | 5.6 | –4.33 | 8.44 |
| NGC 4565 | 0.00410 | 20.11 | 1.7 | 0.02 | 0.006 | 136.0 | 2.9 | –4.32 | 2.95 |
| NGC 4579 | 0.00507 | 20.39 | 1.88 | 0.52 | 0.009 | 154.4 | 4.8 | –2.94 | 0.10 |
| NGC 4594 | 0.00342 | 21.23 | 1.5 | 0.16 | 0.007 | 241.1 | 28.6 | –4.57 | 0.75 |
| NGC 4698 | 0.00334 | 20.91 | 1.91 | 0.10 | 0.0024 | 132.7 | 2.6 | –3.75 | 0.12 |
| NGC 5033 | 0.00292 | 20.01 | 1.7 | 0.28 | 0.017 | 131.4 | 2.5 | –3.41 | 0.60 |
| NGC 5929 | 0.00831 | 20.76 | 1.7 | 0.135 | 0.0408 | 120.6 | 1.8 | –2.66 | 2.97 |
| NGC 5995 | 0.02519 | 21.94 | 1.81 | 2.89 | 0.66 | – | – | – | 1.59 |
| NGC 6221 | 0.00500 | 22.04 | 1.9 | 1.4 | 0.00214 | 111 * | 1.3 | –1.95 | 0.01 |
| NGC 6251 | 0.02471 | 21.88 | 1.83 | 0.14 | 0.057 | 310.7 | 79.3 | –3.35 | 2.66 |
| NGC 7590 | 0.00526 | < 20.96 | 2.29 | 0.12 | 0.017 | 99 * | 0.8 | –2.77 | 0.19 |
| NGC 7679 | 0.01714 | 20.34 | 1.75 | 0.60 | 0.1083 | 96 * | 0.7 | –0.99 | 1.52 |

***Note*:** In the columns are presented: the name of the galaxy; red shift $z$ as reported in NED; $N_H$ is in units of $cm^{-2}$ (from other articles – see references at the end of this paper); photon index Γ (from other references); observed hard X-ray (2-10 keV) flux in units of $10^{-11}$ ergs $s^{-1}$ $cm^{-2}$ (from other references); the extinction-corrected flux of [OIII] λ5007 emission in units of $10^{-11}$ ergs $s^{-1}$ $cm^{-2}$ (observed $F_{[OIII]}$ is from other references); σ – the stellar velocity dispersion of the galaxies (The data for most of the objects is taken from the archive LEDA. The values marked with asterisks are taken from Gu et al. [9]); $M_{BH}$ – the black hole mass in units of $M_\odot$; the Eddington ratios ($L_{Bol}$ / $L_{Edd}$); $N_{ph}$ / $N_{ion}$ ratio. The data in this table is taken from references [2–5] and [8–18].

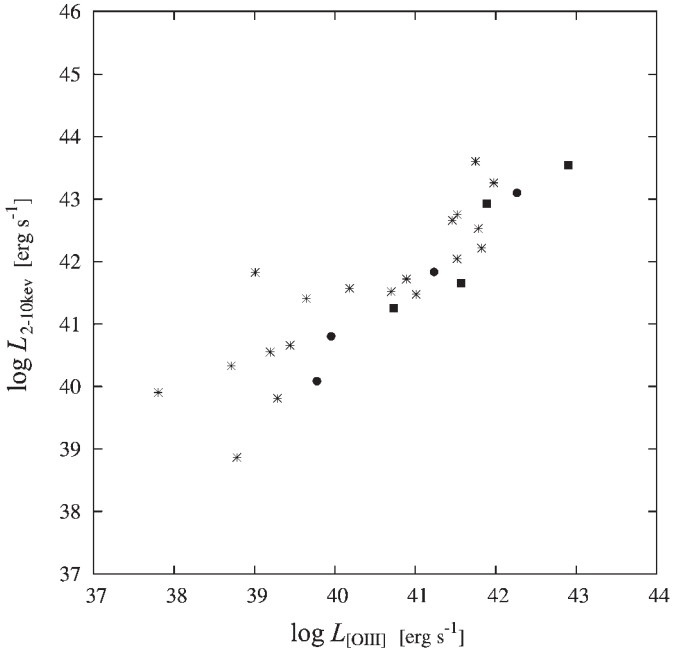


Fig. 2. Relation between the luminosity $L_{2-10\text{keV}}$ and the extinction-corrected luminosity $L_{[\text{OIII}]}$. Symbols are the same as in Fig. 1

At the same time we have calculated $(N_{\text{ph}} / N_{\text{ion}})_{h\nu > 55\text{ eV}}$ from:

$$N_{\text{ion}} = \int_{55eV}^{\infty} \frac{F_{\nu}^{\text{nt}}}{\text{h}\nu} d\nu = 4\pi R_{\text{G}}^2 \frac{F_{\text{h}\nu=55\text{eV}}^{\text{nt}}}{\text{h}\Gamma} = F_{\nu}^{\text{nt}} = F_{\nu_0} (\nu_0 / \nu)^{\Gamma},$$

where $N_{\text{ion}}$ is the number of ionizing photons with $h\nu > 55$ eV provided by the central AGN source, $R_{\text{G}}$ is the distance to the galaxy, $F_{\nu}^{\text{nt}}$ is the flux from the central source, $F_{\nu_0}$ is the flux at $h\nu_0 = 13.6$ eV and $\Gamma$ is the photon index; and

$$N_{\text{ph}} = \frac{\alpha_{\text{G}}(\text{O}^{+2}, T_{\text{e}}) L^{\text{corr}}([\text{O}^{+2}]\lambda 5007) C F^{-1}}{\alpha_{5007}^{\text{eff}}(n_{\text{e}}, T_{\text{e}}) \text{h}\nu_{5007}},$$

where $N_{\text{ph}}$ is the total number of ionizing photons that must be available to produce the observed [OIII] λ5007 emission, $L^{\text{corr}}([\text{O}^{+2}]\lambda 5007)$ is the extinction-corrected luminosity, $\alpha_{\text{G}}(\text{O}^{+2}, T_{\text{e}}) = 5.1 \times 10^{-12}$ cm$^3$ s$^{-1}$ is the recombination coefficient at $T_{\text{e}} \approx 10^4$ K, $\alpha_{5007}^{\text{eff}}(n_{\text{e}}, T_{\text{e}}) = 0.7 \times 10^{-9}$ cm$^3$ s$^{-1}$ is the effective

recombination coefficient at $n_e = 3 \times 10^5$ cm$^{-3}$ and $T_e = 10^4$ K. The covering factor is $CF = 0.07$ [19].

The unabsorbed HBLR Seyfert 2 galaxies of the sample have $(N_{ph}/N_{ion})_{h\nu > 55\ eV}$ larger or approximately equal to 1 and they show an anisotropy because of their hidden central source. Some of the unabsorbed non-HBLR Seyfert 2 galaxies also show an anisotropy, but others have $(N_{ph}/N_{ion})_{h\nu > 55\ eV} < 1$, which is not usual for galaxies with HBLR.

## 3. CONCLUSIONS

Our sample of 27 nearby unabsorbed Seyfert 2 galaxies contains only 4 objects that have a HBLR. Concerning the rest of the sample, there is no evidence for existence of a HBLR. We determined that 12 objects certainly don't have a HBLR. It seems that unabsorbed Seyfert 2 galaxies with HBLR possess a hidden central source and they have $(N_{ph}/N_{ion})_{h\nu > 55\ eV}$ larger or approximately equal to 1.

We also found that it is possible for the objects without HBLR to occupy the areas below as well as above the boundary, $10^{-3}$, for the Eddington ratio. A possible reason is the existence of two sub-types unabsorbed galaxies without HBLR: with lower black hole masses and with more massive black holes in their centres.

**Acknowledgements.** I would like to thank to Ivanka M. Yankulova and Valeri K. Golev for their helpful suggestions.

This research has made use of the NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.

We acknowledge the usage of the HyperLeda database (http://leda.univ-lyon1.fr).

This research was supported by Scientific research fund of St. Kliment Ohridski University of Sofia, Contract 224 / 2008.

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