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MISSING SEYFERT GALAXIES

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RESUMEN

El objetivo de este trabajo es la estimación del número de galaxias Seyfert *faltantes* debido a la ocultación por el polvo del disco de las galaxias espirales. Comparamos la distribución de las inclinaciones de las galaxias anfitrionas de las Sy1s y Sy2s con la de la muestra de control de las galaxias espirales. Encontramos que el número relativo de galaxias Seyfert es mayor para las Seyfert vistas de frente, en las galaxias con $i < 30°$, y es menor en las galaxias muy inclinadas con $i > 61°$ que en las galaxias espirales sin núcleos activos. Concluimos que la diferencia observada se debe a la absorción de los núcleos Seyfert en el disco de polvo de las galaxias inclinadas. Estimamos que las Seyfert faltantes son alrededor del 100% para las Sy1y y del 50% para las Sy2s.

ABSTRACT

The aim of this work is to estimate the number of Seyfert nuclei missing in catalogs due to obscuration by the dust disc in host spiral galaxies. We compared the distribution of inclinations of host galaxies of Sy1s and Sy2s with that of in control sample of spiral galaxies, and found that the relative number of Seyferts is higher in almost face-on galaxies with $i < 30°$ and smaller in highly inclined, $i > 61°$, spiral galaxies without active nuclei. We conclude that the difference found is due to absorption of the Seyfert nuclei by the dust-disc of inclined galaxies. We estimate that about 100% and 50% of the observed Sy1s and Sy2s respectively are missing.

Key Words: galaxies: Seyfert

1. INTRODUCTION

According to the Unified scheme (Miller & Goodrich 1990; Antonucci 1993; Urry & Padovani 1995), the difference between Sy1 and Sy2 galaxies is caused by the orientation of the inner dust torus in relation to the observer. If the opening angle of the torus is pointing towards the observer, and the active galactic nuclei (AGN) with the broad line region (BLR) is directly seen, the galaxy is classified as Sy1. If the orientation of the torus is such that the BLR is hidden, and only the narrow line region is observable the galaxy is classified as Sy2. The ratio of the numbers of Sy1 and Sy2 galaxies determines the opening angle of the putative dust torus. In order to understand the nature of Seyferts it is also important to know the frequency of their occurrence among galaxies.

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Numerous efforts have been made in compiling new a large list of Seyfert galaxies (e.g., Huchra 1977; Véron-Cetty & Veron 2010, and references therein). Some Seyfert nuclei, however, may not be revealed because they are hidden behind the galactic dust-disc. Indeed, Keel (1980), Kirhakos & Steiner (1990), McLeod & Rieke (1995) found, that Seyfert nuclei avoid edge-on galaxies. Malkan, Gorjian, & Tam (1998) also found dust lanes and patches in the central regions of Seyferts. Driver et al. (2008) showed that the role of absorption of starlight by dust grains in galactic discs is substantial. Therefore, the emission of the AGN may be completely hidden by the dust-disc in some highly inclined spiral galaxies, and a certain number of Seyferts may be missing. The real ratio of the numbers of Sy2 and Sy1 galaxies may be altered, and consequently the value of the opening angle of the dust-torus in the Unified scheme may be in error.

It has been suggested that the activity of the galactic nucleus may be triggered by dense envi-

TABLE 1

THE NUMBER OF SPIRAL GALAXIES GALAXIES IN THREE BINS OF INCLINATION i

	$i \leq 30°$	$31° < i < 60°$	$i > 61°$	$i \leq 30°$	$31° < i < 60°$	$i > 61°$
Type	V-CV			SSRS2		
n	56	231	157	163	703	557
$n/n_{\rm total}$	0.13	0.52	0.35	0.12	0.49	0.39

ronments. However, contradictory results have also been obtained. Petrosian (1982), Dahari (1985), Laurikainen & Salo (1995), Dultzin-Hacyan et al. (1999), Storchi-Bergmann et al. (2001), Chatzichristou (2002), Sánchez & Gonzaléz-Serrano (2003), Kouluoridis et al. (2006) showed that Seyferts are found in more dense environments. Meanwhile, Viriani, De Robertis, & van Dalfsen (2000), Schmitt (2001, and references therein) did not find a relation between nuclear activity and environment. The discrepancy may be explained by the inclusion of galaxies with hidden Seyfert nuclei in the control samples.

The first attempt to estimate the number of missing Seyferts was made by Tovmassian (2001). In this paper we reconsider the problem, and estimate the number of missing Seyferts by the study of the distribution of inclinations of spiral galaxies in which Seyfert nuclei mainly reside. We take into account that, as Kinney et al. (2000) showed, the distribution of the angle β between the direction of the radio jet (or the dust torus axis) and the galaxy rotation axis is homogenous in the $0° - 90°$ range. This means that Seyferts should be observed in host galaxies with any inclination angle, if there are no biases in the catalogs. Kirhakos & Steiner (1990) suggested detecting the missing edge-on Seyferts on the basis of the IR and X-ray emission of galaxies. The presence of the broad line region (BLR) emission in some galaxies was detected by observation of the polarized emission scattered by particles located far from the nucleus of a galaxy. Such galaxies are called hidden Sy1s (Sy1h).

2. RESULTS AND DISCUSSION

2.1. *The data*

For our study we used the Sy1 and Sy2 galaxies from the 13-th Edition of the Catalogue of Quasars and Active Nuclei (Véron-Cetty & Véron 2010, hereafter VC-V) with magnitudes $V < 16^m$) and $z < 0.035$. Seyferts hosted in spiral galaxies of morphological types S0/a and later were included in the study. Morphological types of host galaxies of Seyferts were taken from the NED (The NASA/IPAC Extragalactic Database). In accordance with Meurs & Wilson (1984), Osterbrock & Shaw (1988), we joined galaxies with Sy1.2 and Sy1.5 types into the Sy1 category, and Sy1.8s and Sy1.9s into the Sy2 category. The sample of Sy1s includes galaxies of Sy1n type, and the sample of Sy2s includes galaxies classified as Sy1h (hidden Sy1). By cross-checking with the data in the NED we excluded from the studied sample those galaxies whose classification in the NED differed from those in the VC-V catalog. The compiled sample contains 79 Sy1s and 188 Sy2s.

For comparison we compiled two lists of spiral galaxies using the Revised Shapley-Ames catalog of bright galaxies (Sandage & Tammann 1981) and the Southern Sky Redshift Survey (SSRS2) (da Costa et al. 1998). From the latter catalog we used galaxies with radial velocities $V_r < 9000$ km s^{-1} and magnitudes $V < 15.5^m$. From both catalogs we selected spiral galaxies of morphological types from S0/a to Scd. The morphological types were taken from the NED. Galaxies with active galactic nuclei, such as Seyferts, LINERs or those having powerful radio emission were excluded. We did not include in the sample galaxies with any peculiar morphology or members of dense doubles.The compiled list from the Revised Shapley-Ames catalog contains 444 galaxies with measured a and b axes given in the NED. The corresponding list from the SSRS2 catalog consists of 1423 galaxies.

2.2. *Analysis and Results*

We calculated the inclinations i of the galaxies using their observed axial ratio b/a, and binned them in three intervals of inclination $i \leq 30°$, $31° < i < 60°$ and $i > 61°$. In Table 1 we present the numbers of spiral galaxies of the compiled lists from the Revised Shapley-Ames (1st row) and the SSRS2 (3rd row) catalogs in these intervals of inclination. The relative numbers for both catalogs in corresponding bins are given in Rows 2 and 4 of Table 1. Table 1

TABLE 2

THE NUMBERS AND RELATIVE NUMBERS OF SY1S AND SY2S GALAXIES IN THREE BINS OF INCLINATION i

Type	VC-V					
i	$N(<30^\circ)$	$N(31^\circ-60^\circ)$	$N(>61^\circ)$	$N(<30^\circ)/N_t$	$N(31^\circ-60^\circ)/N_t$	$N(>61^\circ)/N_t$
Sy1	20	49	10	0.25	0.62	0.13
Sy2	35	103	50	0.19	0.55	0.26

shows that the distribution of inclinations is not uniform which is evidence of the rather prolate space configuration of spiral galaxies (Vincent & Ryden 2005).

In the absence of biases one would expect the distribution of inclinations of the Seyferts to be the same as that of the normal galaxies, and they should also have about the same relative numbers in the three intervals of inclinations considered. However, we found that the distribution of inclinations of Seyfert galaxies differs from that of spiral galaxies not containing active nuclei (Table 2). A comparison of Table 1 and Table 2 shows that the relative number of both types of Seyferts in almost face-on galaxies ($i \leq 30^\circ$) is higher than in the whole sample of spiral galaxies. The relative number of Seyferts in the second bin is about the same, as for spiral galaxies. At the same time, the relative number of galaxies in the third bin of highly inclined Seyfert host galaxies ($i \geq 61^\circ$) is smaller than that of spirals.

2.3. *The number of missing Seyfert galaxies*

We suggest that the higher abundance of Seyferts seen in almost face-on host spiral galaxies and their paucity in galaxies with very high inclination (third bin) is due to absorption of the emission of the Seyfert nuclei by the dust disc of their host galaxies. In order to estimate the number of missing Seyferts we assume that the relative number of their host galaxies with $i \leq 30^\circ$ ($b/a < 0.86$) must be equal to the corresponding value of spiral galaxies, i.e. about 0.125. Dividing the numbers of Sy1s and Sy2s with inclinations $i \leq 30^\circ$ to the deduced relative number $n_i \leq 30^\circ$ of spiral galaxies with inclinations in the same bin, we estimate the expected total number n_t of Sy1s and Sy2s correspondingly. Subtracting from the estimated total number n_t of Seyferts the corresponding observed number n_o, we find the number n_m of the missing Seyferts. The results of our accounting are presented in Table 3. In the sixth column the relative number n_m/n_t is given.

TABLE 3

NUMBER OF SY1S AND SY2S WITH INCLINATIONS OF THE HOST SPIRAL GALAXIES $i \leq 30^\circ$, THEIR ESTIMATED TOTAL NUMBER, NUMBER OF MISSING ONES AND RELATIVE NUMBER OF MISSING SEYFERTS

	$n_{i\leq 30^\circ}$	n_t	n_o	n_m	n_m/n_o
Sy1	20	160	79	81	1.02
Sy2	35	280	188	92	0.49

Table 3 shows that the number of missing Sy1s is about the same as the number of the known ones. The number of the missing Sy2s is about half of the known ones.

3. CONCLUSIONS

We compared the distribution of inclinations of the host galaxies of Sy1 and Sy2 galaxies from the VC-V catalog with that of the control sample of spiral galaxies not containing AGN from the Revised Shapley-Ames and the SSRS2 catalogs, and estimated the number of Seyferts in which the AGN is hidden by the absorbing dust in the disc of inclined galaxies. We find that about 100% of Sy1s and 50% of Sy2s are missing. The relatively smaller number of missing Sy2s might be expected, since the NLR of some of them are observed at large distances from the galactic plane, where absorption of the dust disc is smaller. The number of missing Seyferts is large and may influence the conclusions on the nature of these galaxies and on the mechanisms of their formation. The relative number of Seyferts among galaxies is thus higher than previously estimated. Taking into account the missing Seyferts increases the opening angle of the dust torus from 90° to 100°. When considering the influence of the environment in activating the Seyfert nuclei, it is necessary to be careful in compiling a control sample: the inclusion of large numbers of highly inclined galaxies in the latter, strongly affected by the disc absorption, may result in erroneous conclusions.

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