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On Possible Ways of Evolution of Seyfert Galaxies

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Abstract
Changes of some physical parameters obtained from the theoretical model calculations in several catalogs for Seyfert galaxies of spectral classes Sy 1 and Sy 2 are analyzed in the work. It is concluded that there is a high probability that the existing evolution of Seyfert galaxies occurs from the spectral class Sy 2 to Sy.

Keywords: Seyfert Galaxy, Spectral Types of Seyfert Galaxies, Evolution Seyfert Galaxies, Active Nucleus Galaxy, Black Hole

Introduction

One of the most interesting objects of extragalactic astronomy, been shell Seyfert galaxies are (hereinafter SG). Despite the fact that they were discovered almost a hundred years ago, they have mysterious objects for the astrophysicists. We have already analyzed the reasons for this situation in our previous works for example, [1], so we will not dwell on this here. At present, with the advent of a large number of so-called sky surveys, as well as satellite observations, the observation al base of the extragalactic objects has expanded (including for SG), and thanks to it, works have begun to appear where several parameters of the SG are determined based on model calculations and the adoption of some generally accepted boundary conditions. Unfortunately, the results obtained from different authors often contradict one another. Therefore, we analyze the theoretical results obtained by some authors, and also find out the possibility of the evolution of SG and the ways of such evolution in this work.

Rotation Velocities and Star Formation Rates of SG

At the beginning, let's plot the dependence (see fig. 1) of the logarithm of the accretion rates of extragalactic matter (log (dM/dt)) on the nucleus from rotation rate of the SG (in our case, this is the FWHM index).

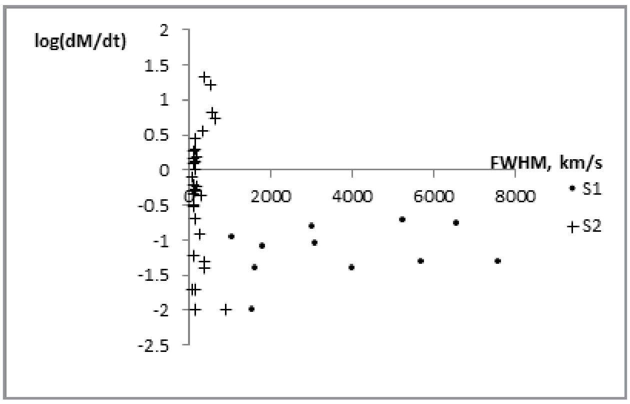

Fig. 1. The dependence of the logarithm of accretion of extragalactic matter on the nucleus from on the speed of rotation of the disk of SG of spectral classes Sy 1 and Sy 2. The points are for SG spectral class Sy 1, and the crosses are for the Sy 2.

These values are obtained directly from observations and the method of their calculation is generally recognized by astronomers. A similar graph has already been published in the work, but in this work we give the values of the logarithm from of (dM/dt) and such a change in scale on the ordinate axis makes this graph more understandable.

We took the data for the graphics from the works [2, 3]. This figure can be interpreted within the framework of classic mechanics. The fact is that the rotation speed of the SG spectral class Sy 1 (as can be seen from the figure) is higher than that of the Sy 2 and the resulting centrifugal force prevents accretion. It is also worth mentioning here that if we accept the hypothesis of the presence of evolution in SG, in which one spectral class passes into another, then at the grossest approximation (if we assume that in SG spectral class Sy 1 the morphological type is mainly SA, and in spectral class Sy 2 it is SB), then it is possible to represent SG as a homogeneous disk in the first case. Rotating around an axis perpendicular to the disk and passing through its center in the second case, as a homogeneous rod rotating around a perpendicular axis the moment of inertia of the disk is less than that of a rotating rod and based on the law of conservation of the angular momentum, the disk must rotate faster than the rod (since the mass of the SG does not change) in the first case. Such a hypothesis requires the presence of some catastrophic mechanism, not yet very clear, for the transformation of one morphological type into another.

From Figure 2 it can be seen that if in the lower part of the figure the mass of the central black hole of the SG of different spectral classes, then only the SG of the second spectral class remain in the upper part of the figure, i.e. in this are mixed case, accretion constantly goes to the core of the SG, which leads to the increase in the mass of the nuclei of these galaxies, as can be seen from the figure.

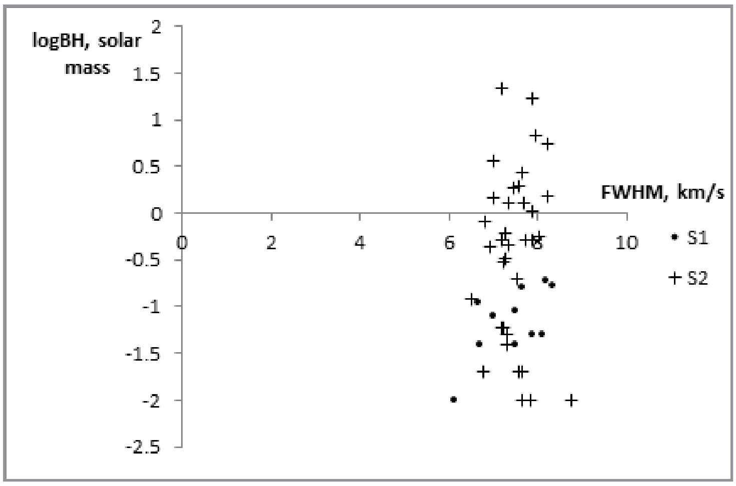

Fig. 2. Dependence of the Mass of the SG Nucleus of Different Spectral Classes for Different Rotational Speeds (Here the Same Designations as in Fig. 1).

Let us now turn to the analysis of such important parameters for the evolution of galaxies as the rate of star formation (SFR). Previously, it was believed that due to the transition from SG spectral class Sy 1 to Sy 2, on average, the color indices become redder, then it indicates the evolutionary path of SG, the rate of star formation falls, more and more low-mass, cold stars are born, i.e. such SG is aging. But then there were works in which see, for example, this statement is questioned. On the contrary, the authors of these works believe that, the rate of star formation increases, and the infrared excess in colors arises mainly due to the fact that a large amount of dust in these in SG spectral class Sy 2 galaxies is heated by the radiation of massive, hot stars [4]. The fact that there is more dust in the SG spectral class Sy2 than in Sy1 is also evidenced by our own research. That is, here there is no need to talk about reducing the rate of star formation.

Let us now consider the SFR values obtained on the basis of model calculations and various boundary conditions. The data are taken from the work and the catalog, in the future we will mainly rely on data from these works [5, 6]. In addition, all extragalactic objects taken from the catalog, as well as from other directories to which we refer in this work, have a redshift of <0.1, i.e. there is no need in this case to make amendments for relativism. From the catalog SG with spectral classes given in were selected. There were 9 – 5 for Sy 1 and 4 for Sy 2 [7].

Table 1. The Values of Star Formation Rates for SG from [6] for four Different Boundary Conditions.

SFR 1, solar mass/year				SFR 3, solar mass/year			
0,297	Sy 1	0,202	Sy 2	1,226	Sy 1	0,463	Sy 2
0,405	Sy 1	0,216	Sy 2	0,064	Sy 1	0,774	Sy 2

0,184	Sy 1	0,047	Sy 2	0,198	Sy 1	0,090	Sy 2
0,404	Sy 1	0,349	Sy 2	0,181	Sy 1	0,048	S 2
1,801	Sy 1			0,662	Sy 1		
mean	б	mean	б	Mean	б	Mean	б
0,618	0,445	0,203	0,011	0,466	0,233	0,343	0,117
SFR 2, solar mass/year				SFR 4, solar mass/year			
0,163	Sy 1	0,014	Sy 2	0,466	Sy 1	0,878	Sy 2
0,220	Sy 1	0,072	Sy 2	0,234	Sy 1	0,371	Sy 2
0,003	Sy 1	0,022	Sy 2	0,483	Sy 1	2,360	Sy 2
0,050	Sy 1	0,515	Sy 2	0,303	Sy 1	0,026	Sy 2
0,019	Sy 1			3,254	Sy 1		
mean	б	mean	б	mean	б	mean	б
0,091	0,010	0,156	0,058	0,948	0,673	0,909	1,059

As can be seen from this table, in two cases the SFR values rise from the spectral class Sy 1 to Sy 2, and for the other two cases, vice versa. If we turn to the work [3], then here for twenty SGs of spectral class Sy 1 and thirty-seven SG Sy 2, the log SFR values calculated for two cases of maximum and minimum surface brightness of HF (log USFR and log LSFR) give in both cases an increase in log SFR from spectral class Sy 1 to Sy 2.

Table 2. Values of Star Formation Rates from the Catalog [3] for SG of Different Spectral Classes.

log USFR					
[Solar mass/year / kpc2]					
Sp	mean	б	Sp	mean	б
Sy 1	0,778	0,093	Sy 2	1,358	0,293
log LSFR					
[Solar mass/year / kpc2]					
Sp	mean	б	Sp	mean	б
Sy 1	0,869	0,123	Sy 2	1,686	0,279

Perhaps this is due to the large number of SGs considered in this catalog, as well as to a more correct consideration of their features in model calculations, since only SG is considered in this catalog, and in all extragalactic objects are considered. But let's try to solve the resulting contradiction on the basis of an analysis of the frequency of supernova explosions in SG, because if the rate of star formation

Table 3. Supernova Explosions in SG.

N	Names	Sp	Type	Morphology
1	NGC 224	Sy 2	I	SA(s)b
2	NGC 1667	Sy 2	Ia	SAB(r)c
3	NGC 2782		IIn	SAB(rs)a pec
4	NGC 3079	Sy 2	Ic	SB(s)cedge-on
	NGC 3079		II	
5	NGC 3147	Unobscured Seyfert 2	I	SA(rs)bc
	NGC 3147		Ia	
	NGC 3147		Ib	
	NGC 3147		Ia	
6	NGC 3362	Sy 2	II pec	SABc
	NGC 3362		II P:	
7	NGC 4258	Sy 2	II*	
	NGC 4258		II P	

8	NGC 4303	Sy 2	II L	SAB(rs)bc
	NGC 4303		II	
	NGC 4303		II	
	NGC 4303		II P	
	NGC 4303		II P	
	NGC 4303		Ia pec	
9	NGC 4704	Sy 2	Ia pec	SB(rs)bc pec
10	NGC 4903	Sy 2	Ia	SB(rs)c
11	NGC 4939	Sy 2	-	SA(s)bc
	NGC 4939		-	
	NGC 4939		II	
	NGC 4939		II P	
12	NGC 5194	Sy 2	Ic	SA(s)bc pec
	NGC 5194		II P	
	NGC 5194		II b	
13	NGC 5427	Sy 2	Ia	SA(s)b pec
14	NGC 5643	Sy 2	Ia	SAB(rs)c
15	NGC 5861	Sy 2	-	SAB(rs)c
16	NGC 6221	Sy 2	Ib/c	SB(s)c
17	NGC 6786	Sy 2	II	SB?
18	NGC 6951	Sy 2	IIn	SAB(rs)bc
	NGC 6951		Ia	
19	NGC 7319	Sy 2	I	SB(s)bc pec
20	NGC 1218	Sy 1	Ia	S0/a
21	NGC 4051	Sy 1h	Ic	SAB(rs)bc
	NGC 4051		II P	
	NGC 4051		Ib/c	
22	NGC 4619	Sy 1.0	Ia	SB(r)b pec?
23	NGC 4639	Sy 1.0	Ia	SAB(rs)bc

Is large, then more massive, hot stars are born and their explosions also often occur. We selected SG from the catalog and compiled Table 3 for them, which provides data on supernova explosions that occurred in these galaxies [8]. As can be seen from Table 3, if SG has a spectral class. Sy 1 had seven supernova flares (of which three are repeated flares in the same galaxy), then SG spectral class Sy 2 already had thirty-seven (where eight are repeated), and if you consider that for example in the data for SG spectral class Sy 1 are about twice as large as for Sy 2, as well as then, that SG in the Universe is only 1-3% of the total number of galaxies, it becomes clear that supernova explosions in Sy2 spectral class Sy 2 are possibly even greater than in ordinary galaxies [9].

But if the rate of star formation in the Sy 2 spectral class Sy 2 is large, based on the frequency of supernova explosions, then it becomes clear where so much dust comes from in these galaxies. In addition, stars begin to be born belonging to different populations of the galaxy, and therefore with different chemical composition, and with a large number of heavy elements. Therefore, consider the values of the metallicity index (unfortunately, we did not find in the literature works where the chemical composition of SG would be were determined) obtained for SG in the works and [10]. The results are summarized in Table 4.

Table 4. Metallicity Index Values Taken from the Works and [10].

Metallicity [6]			
0,004	Sy 1	0,02	Sy 2
0,02	Sy 1	0,02	Sy 2
0,05	Sy 1	0,02	Sy 2
0,05	Sy 1	0,05	Sy 2
0,05	Sy 1		

mean	б	mean	б
0,035	0,0005	0,025	0,0002
Metallicity [10]			
9,18	Sy 1	9,16	Sy 2
9,17	Sy 1	9,12	Sy 2
9,18	Sy 1	9,14	Sy 2
mean	б	mean	б
9,177	0,0005	9,14	0,0004

Here it is not necessary to pay attention to the absolute values of the indices, because in both cases they were calculated according to different formulas. The main thing is that the index grows in these cases from the spectral class Sy 2 to Sy 1.

Table 5. Values of Logarithms of SG Ages for Different Spectral types for four Different Model Calculations.

B	V	L	M*	Sp	B	V	L	M*	Sp
9,306	9,116	8,416	9,729	Sy 1	9,628	9,697	8,830	10,050	Sy 2
8,513	7,979	7,333	9,926	Sy 1	9,077	8,922	7,944	9,616	Sy 2
9,579	9,291	8,306	10,020	Sy 1	10,095	10,101	8,794	10,137	Sy 2
8,860	8,453	7,601	9,996	Sy 1	8,793	8,678	7,599	9,237	Sy 2
9,479	9,122	8,353	10,079	Sy 1					
9,147	8,792	8,002	9,950	mean	9,398	9,349	8,292	9,760	mean
0,202	0,310	0,249	0,018	б	0,336	0,439	0,381	0,174	б

Finally, in Table 5, we present the values of the logarithms of the ages of the SG of the various spectral classes, calculated from four different models using observational data on the brightness of SG in filter B, in filter V, the bolometric luminosity L and the mass of galaxies M*.

Conclusions

The age of SG of different spectral class's increases from Sy 1 to Sy 2 in the first three cases based on the values given in this table and decreases in the last. If the resulting contradiction is considered a consequence of not considering in theoretical, model calculations some features of SG, then the probability of evolution of SG from spectral class Sy 2 to Sy 1 is seriously increased, because some difficulties associated, for example, with the increase in metallicity during the transition from Sy 2 to Sy are removed.

And finally, we can refer to the fundamental principle of our Universe that entropy grows over time, which no one has yet cancelled.

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