АСТРОФИЗИКА

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ON A POSSIBLE MECHANISM FOR THE START OR RESUMPTION OF ACTIVITY OF RADIO GALAXIES IN CLUSTERS OF GALAXIES

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We study the close proximity of the well-known and well-studied 3C31 class FRI radio galaxy in order to reveal the influence of the environment on an extragalactic radio source. It was shown that about 110 million years ago the galaxies NGC 380 and NGC 386 were located near the galaxy NGC 383 (the parent galaxy of 3C31). On the other hand, the modeling of the spectral characteristics of the radio emission of the central part of the radio galaxy 3C31 gives an estimate of the age of the central jet of about 100 million years. Therefore, it can be assumed that one of the possible reasons for the appearance or resumption of the radioactivity of the galaxy NGC 383 may be a triple close passage of galaxies.

Keywords: *galaxies - radio galaxies - clusters of galaxies - environment of galaxies*

1. *Introduction*. The environment surrounding the galaxy can play an important role in the formation and evolution of various types of activity in galaxies. In particular, this applies to extragalactic radio sources and activity in radio emission [1]. It is known that radio galaxies are often members of clusters of galaxies, and AGN activity is much higher in the central parts of clusters than in the rest of the metagalactic space [2,3]. This can be partly explained by the fact that the host galaxy of radio galaxies is usually massive galaxy ($M > 10^{12}$ solar masses), and they are often the central objects of clusters.

However, the relationship between AGN activity and galaxy clusters is still not fully explained. In this regard, it is very important to study the relationship between the physical and morphological features of radio galaxies and the characteristics of galaxy clusters in which these radio galaxies are located. Such characteristics can be the number, concentration and morphological composition of galaxies in clusters, the presence of hot and cold gas and dust in clusters, the presence of background radiation in different frequency ranges, and others.

Radio galaxies are divided into different types according to their physical and morphological features. One of the well-known classifications of extended radio galaxies is the (FR) classification of Fanaroff and Riley [4], which is based on the radio brightness distribution over the radio image. Radio galaxies with relatively

lower radio luminosity, in which the radio brightness decreases from the center to the edges, are classified as I class radio galaxies (FRI), and radio galaxies with higher radio luminosity, in which the radio brightness increases from the center to the edges of the II class (FRII). At present, the Fanaroff-Riley dichotomy has been studied quite well and many other differences in physical and morphological features have been found for different classes of radio galaxies. In particular, in our works, we studied the correlations between the physical and morphological features of extragalactic radio sources for different Fanaroff-Riley classes. A correlation was found between the optical and radio axes of nearby radio galaxies [5], a correlation of the ellipticity of parent optical galaxies associated with radio galaxies of different classes [6], a correlation of the average radio polarization angles with the radio axes [7], etc.

In [8] it was shown that the radio activity of FRIs are mostly triggered by different mechanisms than in FRIIs. One can probably expect some connection also between the FR class and the physical and morphological features of the cluster in which these radio galaxies are located. It can be due to the interaction between galaxies when they randomly pass close to each other. There are lot of papers where the activity of galaxies in the radio range is trying to be explained by merging processes [9,10]. In particular it was shown that in galaxy systems where traces of close interaction (merging) are observed, the percentage of active galactic nuclei is higher [11]. All of this may suggest that close transits of galaxies may be the cause (be a trigger) for the start of radio activity.

In this work, in order to reveal the influence of the environment on an extragalactic radio source, we study the close proximity of the well-known and well-studied 3C31 class FRI radio galaxy.

2. *Observational data.* The 3C31 class FRI radio source has been identified with the NGC 383 galaxy, which is the central object of the group of galaxies, which in turn is a member of the Perseus-Pisces supercluster [12] and has been studied quite well. Numerous results and useful data have now been obtained for these objects [13-18]. Of these, here we highlight some of the data of interest to us, which can be used in the present work.

Fig.1 and 2 show optical images of the region with the central galaxy NGC 383 over lied on the radio maps. On figures there are maps of the radio image of the FRI class 3C31 radio galaxy at different frequencies, 145, 360, 615, and 1400 MHz corresponding to LOFAR, VLA, GMRT and FIRST observations, respectively. It must be noted that the Fig.2 is taken from the paper [19].

It can be seen from the Fig.1 that the group of galaxies with the central object NGC 383 has the form of a chain whose direction coincides well with the direction of the radio image of the 3C31 radio galaxy. High-resolution radio

observations have detected two oppositely directed jets within 10 kpc from the galaxy's core (Fig.2). Radio jet simulations [16] have shown that the direction of

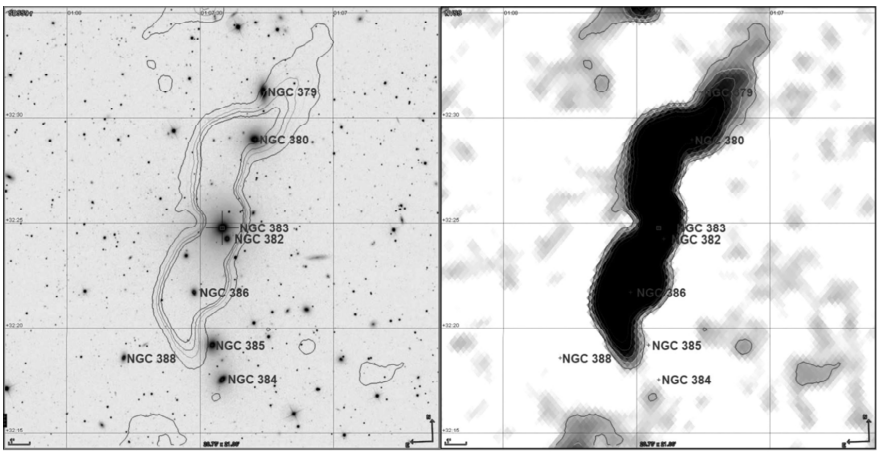

Fig.1. The region of a group of galaxies with the central object NGC 383 and overlaid radio Source 3C31 of the FRI class at the frequency of 1400 MHz.

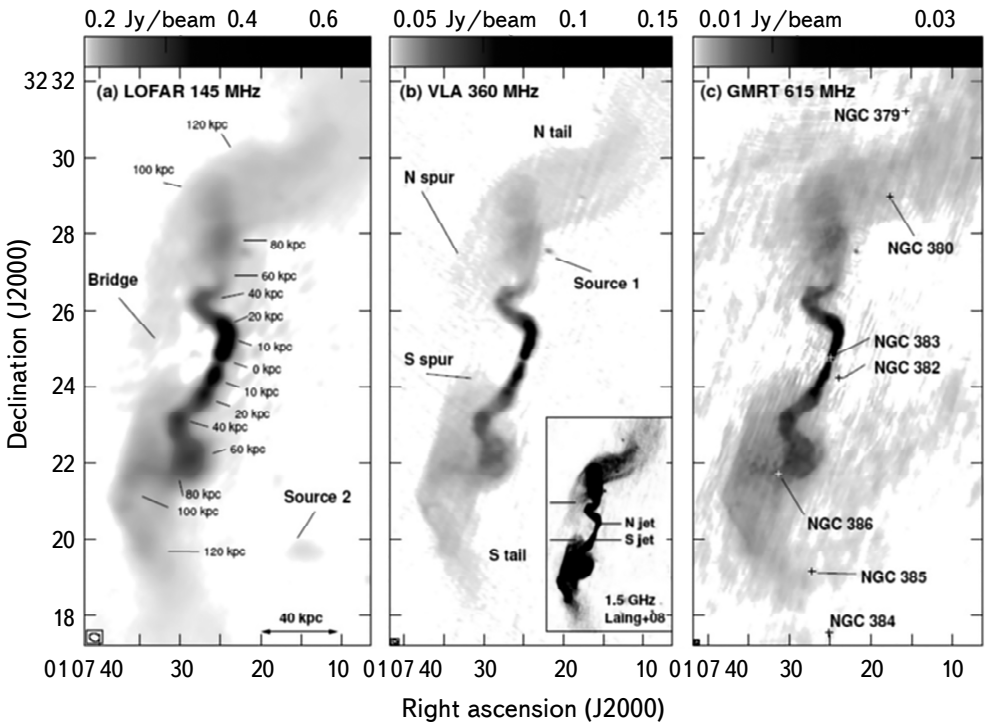

Fig.2. Radio image maps of the FRI class radio galaxy 3C31 at three different frequencies (from[19]).

the jet is approximately 52° with the line of sight. Moreover, the northern part of the jet approaches the observer, while the southern part moves away.

3. *Data analysis*. In Table 1 we bring the coordinates, redshifts and types of galaxies included in the galaxy group with central galaxy NGC383 from database NED.

From the analysis of the coordinates and redshift data of galaxies, as well as from Fig.1 and also Fig.2 from [19], it can be seen that the elliptical galaxies NGC380 and NGC386 are located respectively in the northern and southern parts of the 3C31 radio image. These galaxies, together with the central SA0 type galaxy of the group NGC383 (which is the parent galaxy of the radio galaxy 3C31), are on the same line, the direction of which coincides with the direction of inner part of the radio jet with great accuracy. Moreover, the relative radial velocity of the NGC380 galaxy with respect to the central galaxy NGC383 is directed towards the observer as the velocity of northern part of the jet, when the relative radial velocity of NGC386 is directed away from the observer as the velocity of southern part of the jet. If we assume that the galaxies NGC380 and NGC386 are not

Table 1

OBSERVATIONAL DATA OF GALAXIES INCLUDED IN THE GROUP WITH THE CENTRAL OBJECT NGC 383 FROM DATABASE NED

Name	RA deg	DEC deg	Redshift z	Morphology
NGC 379	16.815375	32.520361	0.01861	S0
NGC 380	16.823296	32.482922	0.01476	E2
NGC 382	16.849463	32.403864	0.01744	E
NGC 383	16.853995	32.412559	0.01700	SA0
NGC 384	16.854596	32.29245	0.01412	E3
NGC 385	16.863524	32.319533	0.01659	SA0
NGC 386	16.880387	32.361994	0.01853	E3
NGC 388	16.946442	32.309963	0.01816	E3

only projected onto radio images, but are located inside the radio-emitting region, then we can make the following plausible assumption that not only the directions of the relative radial velocities of these galaxies, but also the directions of spatial velocities coincide with the directions of motion of the northern and southern radio jets. Hence, the galaxies NGC380 and NGC386 are moving away from the central galaxy NGC383 along the directions of the radio jets of the 3C31 radio galaxy. It is interesting to determine the approximate time for which these galaxies covered the distance from NGC383.

In this study will be used standard cosmology, applying the values

$H_0 = 70\,\mathrm{km\,s^{-1}\,Mpc^{-1}}$, $\Omega_m = 0.3$ and $\Omega_\Lambda = 0.7$. At the redshift of the radio galaxy 3C31 ($z = 0.0169$; [16]), its distance will be $D = 73.3$ Mpc, which corresponds to an angular scale of 0.344 kpc per arcsecond [19].

The data given in Table 1 were used to calculate the distance projections of the galaxies NGC380 and NGC386 from NGC383 on the image plane. To do this, using the coordinates of the galaxies, the corresponding angular distances were calculated, and then the projections of the distances of the galaxies were calculated using the above-mentioned angular scale of 0.344 kpc per arc second. Given the values of these projections and the fact that, as was assumed above, the real distances, as well as the direction of the radio jets, are 52° with the line of sight [16], it is possible to determine the real distances of the galaxies NGC380 and NGC386 from NGC383.

The relative radial velocities of the galaxies NGC380 and NGC386 compared to NGC383 can be calculated from the relative redshifts. The relative real velocities are also based on the assumption that they are 52° with the line of sight. The results of these calculations are shown in Table 2. We give the following data in Table 2: respectively in column 1 the name of the galaxy, 2 - redshift difference between the given galaxy and NGC383, 3 - corresponding relative radial velocities, 4 - real relative velocities, 5 - distances of the galaxies from the central NGC383 galaxy on the picture plane, 6 - the real distances of the galaxies, 7 - the time of the removal of the galaxies from the central object.

Table 2

RESULTS OF CALCULATIONS

Galaxies	Δz	ΔV	ΔV_0	d	d_0	T
		km/s	km/s	kpc	kpc	My
NGC380	-0.00224	-672	-1092	97.07	123.2	110
NGC386	+0.00153	+459	745.5	70.64	89.64	118

4. *Discussion of the results*. Table 2 shows that the galaxies NGC380 and NGC386 were near the galaxy NGC383 about 110 million years ago. A very close passage of these three galaxies then probably occurred, after which the recession of the galaxies NGC380 and NGC386 from the more massive central galaxy NGC383 began. A natural question arises whether such a close passage can be the cause (trigger) of the beginning of radioactivity of the central galaxy. Note that the question of the cause of the start or recurrence of radioactivity is studied in many works (see, for example, [20]), but there is still no clarity in this issue. Based on the results of our calculations, the reason for the resumption of radio activity of 3C31 radio galaxy can be considered the close passage of the three

above-mentioned galaxies about 110 million years ago. A reliable argument for this assumption can be considered that the modeling of the spectral characteristics of the radio emission of the central part of the radio galaxy 3C31 gives an estimate of the age of the central jet of about 100 million years [19]. Mentioned estimation agrees very well with the age of the triple transit of galaxies. This result with the good coincidence of the direction of the central jet with the direction of the removal of the galaxies NGC380 and NGC386 from the central galaxy NGC383 can be taken as an indirect argument for above-mentioned consideration.

As another indirect argument can be the assumption that elliptical galaxies NGC380 and NGC386 in the result of triple close passage of galaxies probably loss their gas component by the accretion to the central SA0 type galaxy NGC383 which is rich in gas and dust component [15].

Thus, from all of above-mentioned arguments it can be assumed that one of the possible reasons for the appearance or resumption of the radio activity of galaxies may be the triple close passage of galaxies.

Of course, for such an important assumption, the given single example is not enough, but we believe that it makes sense to continue investigating in this direction.

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О ВОЗМОЖНОМ МЕХАНИЗМЕ НАЧАЛА ИЛИ ВОЗОБНОВЛЕНИЯ АКТИВНОСТИ РАДИОГАЛАКТИК В СКОПЛЕНИЯХ ГАЛАКТИК

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С целью выявления влияния окружающей среды на внегалактические радиоисточники, мы исследовали близкое окружение известной и хорошо изученной радиогалактики класса FRI 3C31. Показано, что около 110 млн лет

назад галактики NGC 380 и NGC 386 располагались вблизи галактики NGC 383 (родительской галактики 3C31). С другой стороны, моделирование спектральных характеристик радиоизлучения центральной части радиогалактики 3C31 дает оценку возраста центрального джета примерно в 100 млн лет. Поэтому можно предположить, что одной из возможных причин появления или возобновления радиоактивности галактики NGC 383 может быть тройное близкое прохождение галактик.

Ключевые слова: *галактики - радиогалактики - скопления галактик - окружение галактик*

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