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A study of active galaxies in groups of galaxies and in the field.

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Abstract

We study regions with radius of 500 pc around of the central radio galaxies from our sample. For this study were chosen about 30 nearby 3C radio galaxies of different FR types. We bring the maps of optical galaxies that are overlaid on the radio map of 3C radio source. It was used also the maps of these regions in all available wavelength. Here we present more detail analyses and new results for the radio galaxy of FRI type 3C31.

The dependencies of the morphological types of the first and second ranked group galaxies on the magnitude gap were studied. It is shown that there is no increase in the relative number of elliptical galaxies among the first and second ranked group galaxies with large magnitude gaps. Some results are presented on studies of a sample of about hundred galaxies ("100SBS") from two adjacent fields of SBS, which have spectral data in SDSS. Comparative analysis was done between two classifications that the 100SBS objects got - from one side Starburst or Starforming in SDSS, from the other - SfGcont and SfGneb, with a possibility of further detailing in accordance to our scheme for star-forming galaxies.

Keywords: *Radio galaxies, groups of galaxies, FR type, SBS fields, galaxie formation*

1. Introduction

The study of active galaxies is one of traditional direction of Byurakan observatory. In this paper we present some of recent works carried out in the department of active galaxies of BAO. These are: The investigation of properties of the neighborhood of giant extragalactic radio sources. The study of galactic groups and clusters. The spectrophotometric observations of SBS galaxies. The study of formation and morphology of magnetic fields of galaxies and particularly in our Galaxy etc.

Extragalactic radio sources mainly are divided on two groups: compact and extended radio sources. One of the well-known classifications of extended radio galaxies is the (FR) classification of Fanaroff and Riley (Fanaroff & Riley, 1974), 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). Figure 1 shows examples of extragalactic radio sources of FRI and FRII types.

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. Partly in our early studies a correlation was found between the optical and radio axes of nearby radio galaxies (Andreasyan & Sol, 1999), a correlation of the ellipticity of parent optical galaxies associated with radio galaxies of different classes (Andreasyan & Sol, 2000), a correlation of the average radio polarization angles with the radio axes (Andreasyan et al., 2002), etc.

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These large differences in morphology and physical properties of different classes of extragalactic radio sources can be due to differences in parent optical galaxies or in differences of the extragalactic medium around the radio source in which the radio source is expanding. In order to reveal the influence of the environment on extragalactic radio source, we study the close proximity (regions with radius of 500 pc around of the central radio galaxies) of the well-known Giant radio sources 3C 31, 3C 449, NGC 315, NGC 6251 from our sample of about 30 nearby 3C radio galaxies of different FR types chosen from Andreasyan & Abrahamyan (2021).

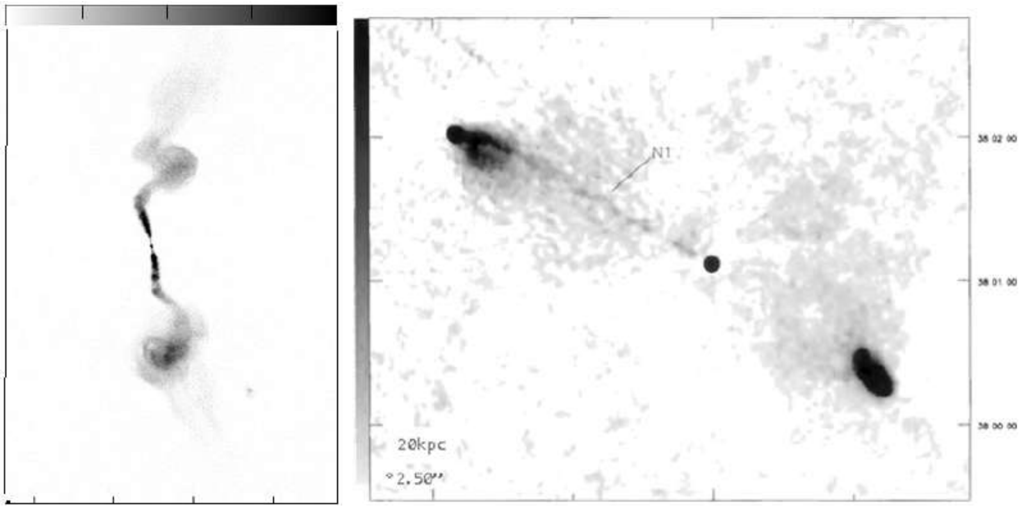

Figure 1. Extragalactic radio sources of FRI (left) and FRII (right).

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2. The study of the neighborhood of radio galaxies.

For the study we construct the maps of optical galaxies that are overlaid on the radio map of 3C radio source. We use also the maps of these regions in all available wavelength. Here we present more detail analyses and new results for the radio galaxy of FRI type 3C 31.

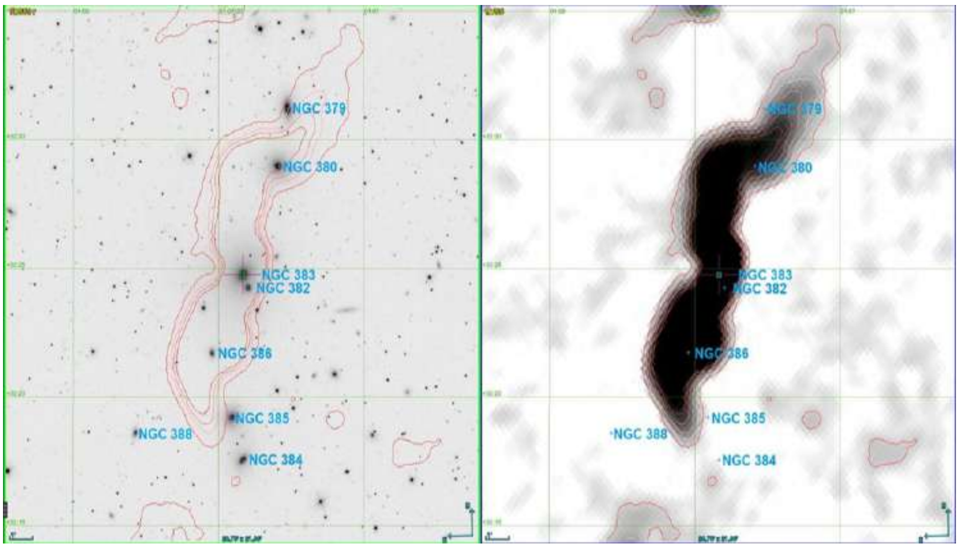

Figure 2. The region of a group of galaxies with the central object NGC 383 and radio source 3C 31 of the FRI class at a frequency of 1400 MHz.

The 3C 31 class FRI radio source has been identified with the NGC 383 parent galaxy, which is the central object of the group of galaxies, which in turn is a member of the Perseus-Pisces supercluster (Sakai et al., 1994) and has been studied quite well. Numerous results and useful data have now been obtained for these objects (Croston & Hardcastle, 2014, Hardcastle et al., 2002, Laing & Bridle, 2002, Martel et al., 1999, Parma et al., 1999, Strom et al., 1983). Of these, here we highlight some of the data of interest to

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us, which can be used in the present work. On figure 2 we bring the radio map of 3C31 at frequency of 1400 MHz (corresponding to FIRST observations) with the overlaid optical region with the central galaxy NGC383. As it is seen a group of galaxies in the form of a chain has the direction of the radio image. It is more obvious on the Figure 2 of same region from the paper Heesen et al. (2018) at different frequencies, 145, 360, and 615 MHz corresponding to LOFAR, VLA, and GMRT observations, respectively.

From figures we see that the elliptical galaxies NGC 380 and NGC 386 are located respectively in the northern and southern parts of the 3C 31 radio image. These galaxies, together with the central SA0 type galaxy of the group NGC 383 are on the same line, the direction of which coincides with the direction of central part of radio image with great accuracy (Heesen et al., 2018). Radio jet simulations (Laing & Bridle, 2002) have shown that the direction of the central jet is approximately 520 with the line of sight. Moreover, the northern part of the jet approaches the observer, while the southern part moves away. On the other hand, the analysis of the redshifts of the mentioned optical galaxies shows that the relative line of sight velocity of the northern galaxy NGC 380 compared to the central galaxy NGC 383 is directed towards the observer, and the relative velocity of the southern galaxy NGC 386 is directed away from the observer. This probably suggests that the direction of the spatial velocities of these galaxies also coincides with the direction of the velocities of the radio jets and, therefore, galaxies NGC 380 and NGC 386 move away from the central galaxy NGC 383 in opposite directions coincide with the direction of the radio jets. We calculated the time of removal of galaxies from the central galaxy. The calculation results are shown in Table 1. Δz is difference of redshifts from the central galaxy NGC 383, ΔV and ΔV_0 – the relative line of sight and spatial velocities respectively, d and d_o -the projected on the sky and spatial distances, T- the time of removal of galaxies.

Table 1. Results of Calculations.

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

The table shows that the galaxies NGC 380 and NGC 386 were near the galaxy NGC 383 about 110 million years ago. A very close passage of these three galaxies then probably occurred, after which the recession of the galaxies NGC 380 and NGC 386 from the more massive central galaxy NGC 383 began. A natural question arises whether such a close passage can be the cause (trigger) of the beginning of radioactivity of the central galaxy. A reliable argument for such 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 (Heesen et al., 2018).

3. The spectrophotometric observations of SBS galaxies.

An important direction in the work of our department is the spectrophotometric observations of galaxies of the Second Byurakan Survey (SBS) (Hakopian, 2021). The observations were carried out with the 2.6m telescope of the Byurakan observatory and the 6m telescope of the SAO of the Russian Federation. Here are some works that are part of a large program launched in 2013 (Hakopian, 2014). Out of 7 preselected areas, nearby ($0.01 < z < 0.029$) galaxies were studied in two areas 4 and 5 (Fig. 3). Approximately 80% of galaxies turned out to be galaxies with active star formation (SfG - star-forming galaxy). Spectral data from SDSS (Sloan Digital Sky Survey-www.sdss.org) were also known for them.

The studied SfG star-forming galaxies, by some analogy with (Terlevich, 1997), were classified into two classes SfGcont, i.e. star-forming in continual phase and SfGneb, i.e. star-forming in nebular phase. Each class was divided into 5 subclasses according to spectral data. Such data are the intensities and equivalent widths of the Balmer $H\alpha$ line. For SfGcont 1, the equivalent widths start from EW($H\alpha$) = $5\mathring{A}$, and for SfGneb 1 from EW($H\alpha$) = $100\mathring{A}$. Below are examples of such galaxies and their spectra (fig.4).

4. The study of galactic groups and clusters.

Another direction of work of our department is the finding and studying the physical properties of galactic groups (Mahtessian et al., 2018). The accepted mechanism for the evolution of galaxies in groups is based on the process of merging of galaxies. However, there is another, opposite mechanism of group

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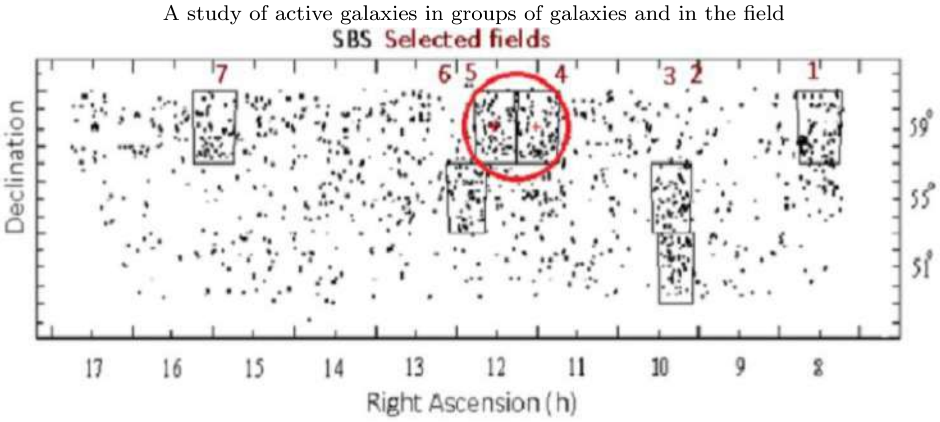

Figure 3. The areas of the study

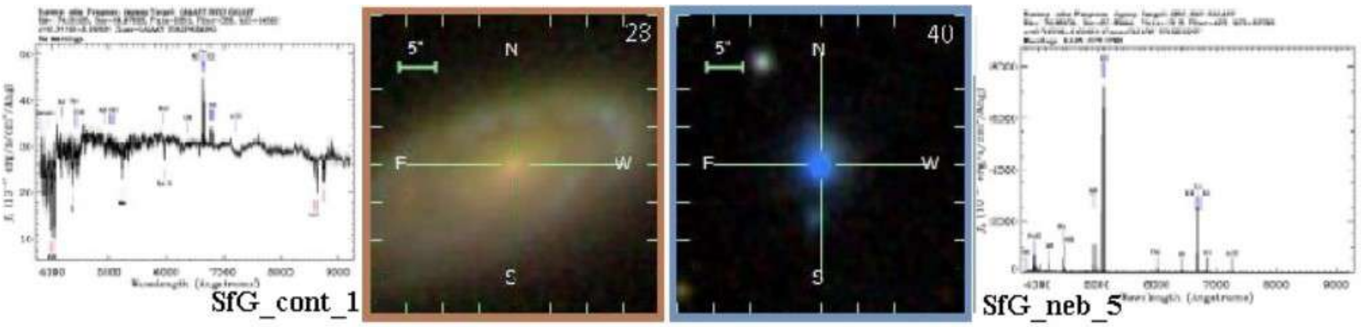

Figure 4. Examples of galaxies classified as SfGcont 1 and SfGneb 5.

evolution corresponding to the concept of V. Ambartsumyan. Many observational data can be successfully explained by both mechanisms, but some data are better suited to the second mechanism.

According to the galaxy merger mechanism, the mass and luminosity of the central galaxy should increase with time, and the difference between the luminosities of the first and second most luminous galaxies should also increase. Moreover, the main galaxy of the group becomes elliptical. According to the second scenario, such an effect should not be observed. The above mentioned has been verified by statistical analysis of data from a large list of galaxy groups that is complete up to a magnitude of 15.5 m (Mahtessian, 2011, Mahtessian & Movsessian, 2010). As a result of the analysis, the expectations corresponding to the merger mechanism were not confirmed, which shows in favor of the mechanism of the Byurakan concept.

5. The study of formation and morphology of magnetic fields of galaxies

There are regular magnetic fields with inductions of several micro gauss observed in numerous galaxies. The generation of these fields is explained by the dynamo associated with motions of the interstellar medium in appropriate objects. The growth of magnetic fields is exponential and these become stabilized when the equipartition of energy between magnetic fields and turbulent motions is reached. For starting this generation mechanism, some initial "seed" magnetic fields are necessary, and these fields are not explained within the dynamo theory. Among approaches explaining the magnetic fields in galaxies, there is the so-called Biermann battery mechanism (Mikhailov & Andreasyan, 2021). This mechanism relates to fluxes of protons and electrons flowing from the central portion of the object, with these fluxes being dragged by rotational motions of the medium. This results in circular currents, which are different for various particles due to their different masses. The total current becomes nonzero and generates the magnetic field. We have constructed a self-consistent model and derived an integral equation, which permits both to determine the order of magnitude of the initial magnetic field and to study in detail its spatial structure.

Another direction of the study of magnetic field structure of our Galaxy and Metagalactic Space based on the use of Faraday rotation data of extragalactic radio sources and pulsars. The plane of polarization of radiation is rotating when this radiation pass thru the magnetoionic medium. The rotation depends from the wavelength of radiation, and this gives the possibility to find so cold rotation measure (RM) by formulae:

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$$RM = d\Psi/d(\lambda^2) = \alpha \int n_e B_L dL, (\alpha = 8.1 * 10^5), \tag{1}$$

For pulsars from the observations it is possible to obtain also dispersion measure (DM). It depends on the effect that the same signal in different frequencies reaches the observer at different times.

$$t_2 - t_1 = (2\pi e^2)(1/\omega_2^2 - 1/\omega_1^2)DM, \tag{2}$$

$$DM = \int n_e dL, \tag{3}$$

Here $d\psi$ – is the difference of plane of polarization in different wavelength λ, t –is the time of receiving the radio signal from pulsar, ω – is the frequency of radio wave. In these formulas, integration is carried out over the entire traversed path of radiation (L in parsecs) from the object to the observer. Formula 3 makes it possible to determine the distance of a pulsar with the known electron density distribution in the Galaxy, and Formula 1 together with formula 3 makes possible to determine the average component of the tension of interstellar magnetic field $[B_L]$ on the line of sight in micro gauss (μG).

$$< B_L >= (1/\alpha)(RM)/(DM) = 1.23 * (RM)/(DM), \tag{4}$$

This gives a possibility to study the magnetic field in different directions (e.g. Andreasyan et al., 2020). On the figure 5 we bring some results for Galactic magnetic field from above mentioned paper where was shown that in the galactocentric ring with the radius $5kpc < R < 7kpc$ the magnetic field has an anti-clockwise direction.

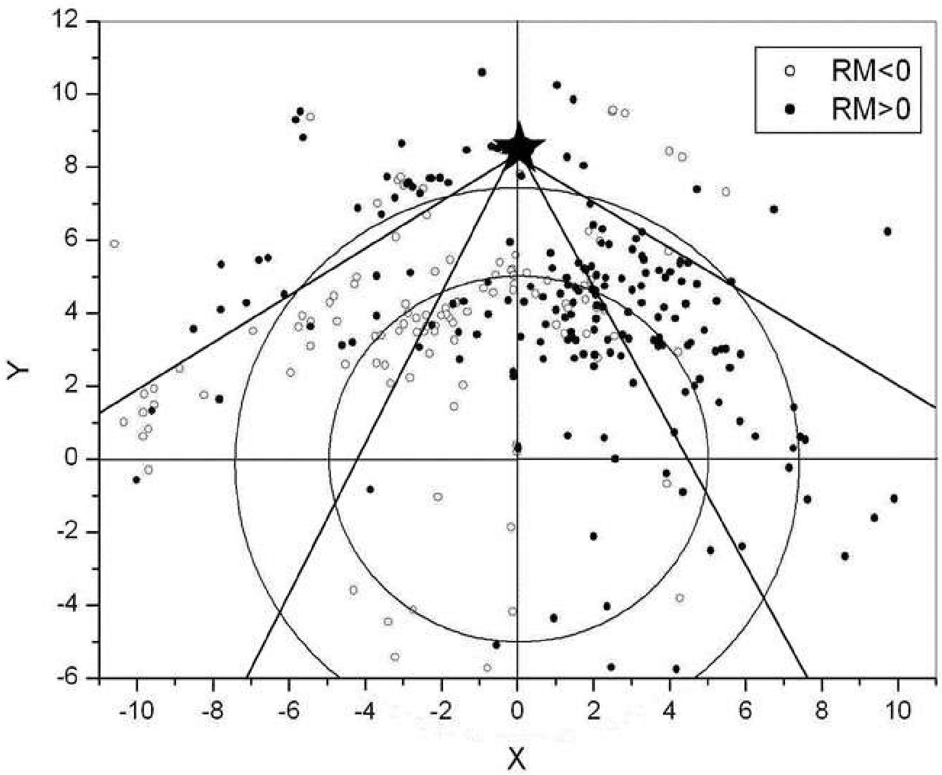

Figure 5. The Galactic distribution of RM signs of pulsars with $|RM| > 200rad/m^2$.

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