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Active galaxies in the field and in Galaxy Clusters

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NAS RA Byurakan Astrophysical Observatory after V. A. Ambarsumian

Abstract

We review the current activities of the Department of Active Galaxies of Byurakan Astrophysical Observatory. The studies include broad areas, ranging from manifestations of activity in our galaxy, other galaxies and clusters of galaxies to the study of magnetic fields, the formation of these fields, and cosmological questions.

Keywords: *active galaxies, magnetic field, clusters of galaxies*

1. Introduction

The study of active galaxies is one of the traditional directions of Byurakan observatory. Here are presented some of recent works carried out in the department of active galaxies of BAO. There are

- The spectrophotometric observations of SBS galaxies,
- The study of formation and morphology of magnetic fields of galaxies and particularly in our Galaxy,
- The investigation of properties of the neighborhood of giant extragalactic radio sources,
- The study of galactic clusters et.c.t.

2. The spectrophotometric observations of SBS galaxies.

- Detailed studies of the individual galaxies, which we performing, are based on the data from panoramic/ wide-field spectroscopy, provided from observations with multipupil spectrographs. The one another object we investigate is SBS 1001+555, one of the nearest SBS galaxies with redshift z=0.0037 (fig.1a). Observations of the main region of star formation in it we carried out with the 6-m telescope using the multipupil fiber spectrograph MPFS. The observed region includes the brightest in the optical range condensation, contritely standing out from the diffuse background, which is composing the elongated shape of the galaxy. An analysis of the surface distribution of the parameters of the emission in the most intense in the obtained spectrum (fig.1b) the Ballmer H_α line (fig.1c) revealed, in particular, the presence besides the main HII-region of three faint secondary HII-regions; this is indicative of the ongoing star-formation processes in the galaxy. The results obtained on the kinematics of the gases in the velocity field, on the spectral features of the HII-regions along with other available multiwavelength data, including data from IRAC mission, revealed new interesting details, connected to activity processes that undergoing in SfG galaxies (Hakopian, et all. 2022).
- One of important directions in the work of our department is the spectrophotometric observations of galaxies of the Second Byurakan Survey (SBS) as a base for complex investigations of activity processes. 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 of the last works that are part of the large program, began with completion of the follow-up spectroscopy for about 500 objects

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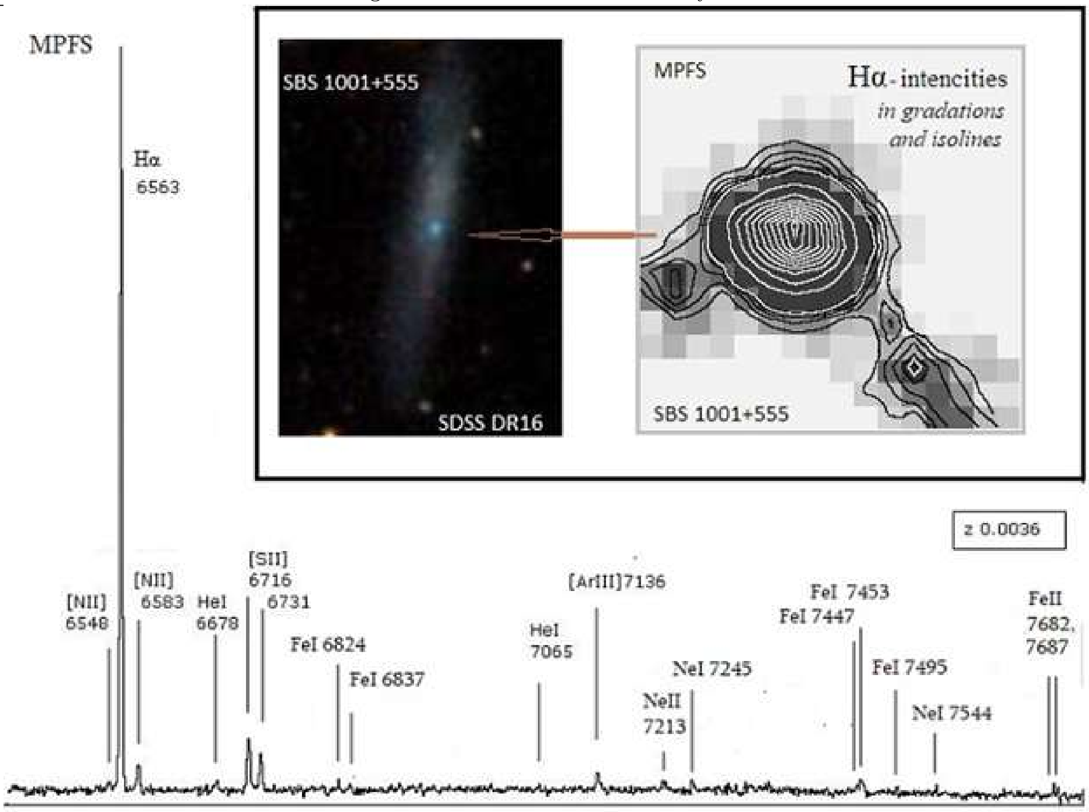

Figure 1. An optical and H_α images (a; b), and optical spectra (c) of SBS galaxy 1001+555.

composed the samples in the seven 16sq.deg selected fields of the survey (fig 2).
The study provided for the two adjacent fields, 4th and 5th, got name “100sbs”. About hundred nearby galaxies (0.01<z<0.12), composing approximately 80 % of these two samples, are galaxies with active star formation, being classified as SfG (star-forming galaxy) in our “adapted scheme”.

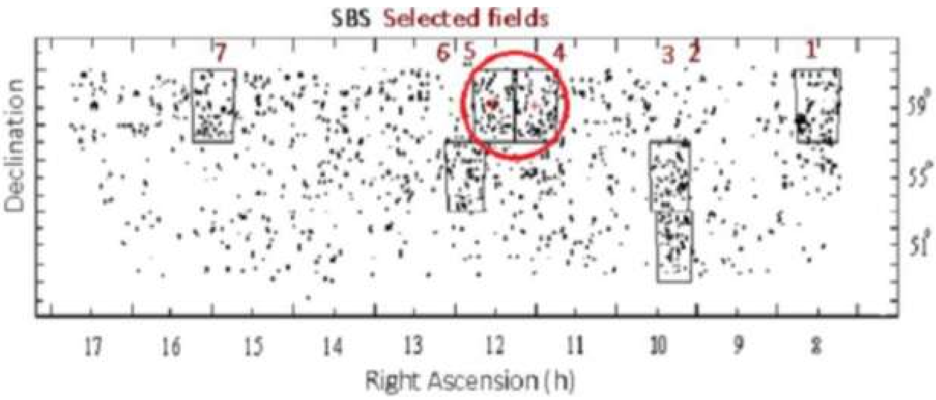

Figure 2. 7 selected fields of the survey.

In its frames we consider two SfG-classes - SfGcont, i.e. star-forming in continual phase and SfGneb, i.e. star-forming in nebular phase. The usage and comparative analysis of spectral data available from SDSS (Sloan Digital Sky Survey) for all “100sbs” and those we obtained earlier allowed, in particular, improving classification. Each of Sfgcont and SfGneb classes was divided into 5 subclasses according to spectral data, primarily, the intensities and equivalent widths of the Ballmer H_α line. For SfGcont 1, the equivalent widths start from EW(H_α)=5^0A, and for SfGneb 1 from EW(H_α) = 100^0A. Below (fig.3) are examples of such galaxies and their spectra. (Hakopian 2021).

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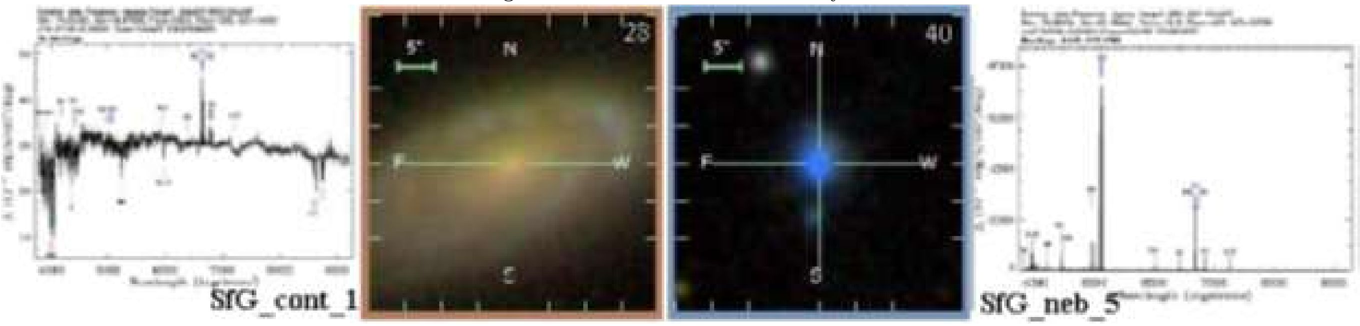

Figure 3. Examples of SfGcont and SfGneb classes of galaxies.

3. The study of environment of radio galaxies of different FR classes

Studies of extended radio galaxies belonging to different morphological classes (FR classification) (Fanaroff, Riley 1974), and their surroundings are carried out (Fig.4). Powerful radio galaxies are mostly supergiant galaxies at the center of galaxy clusters

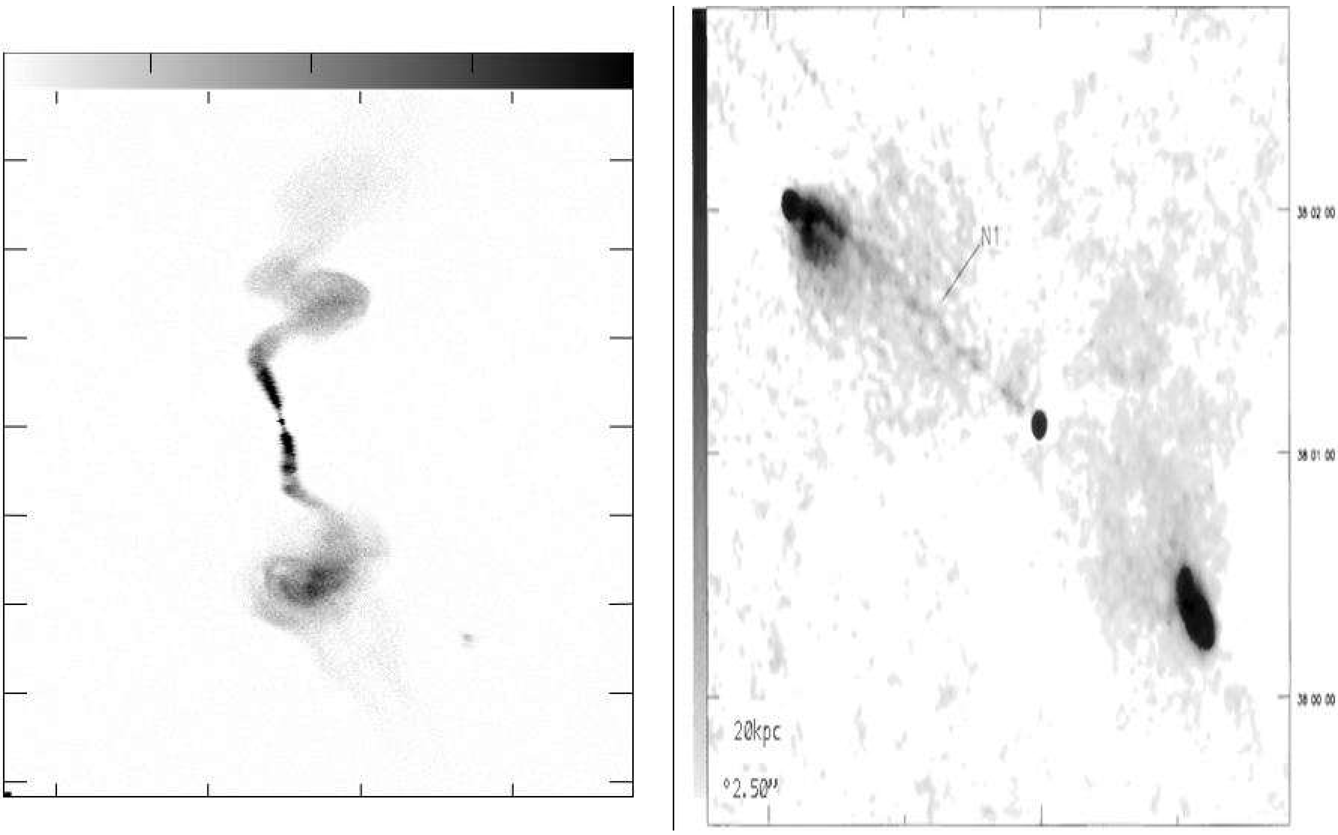

Figure 4. Extragalactic radio sources FRI 3C449 (left) and FRII 3C111(right).

The difference of morphology of FRI and FRII classes of radio galaxies is obvious. This difference may be due to the physical properties of the host optical galaxy or the state of the environment. Here we study the second possibility. We investigate regions with radius of 500 pc around of the central radio galaxies from our sample (Andreasyan; Abrahamyan 2021). 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. The first investigated extragalactic radio sources are 3C31, 3C449, NGC315, NGC6251. Here we present more detail analyses and new results for the radio galaxy of FRI type 3C31. 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 (Sakai et al. 1994) and has been studied quite well. Numerous results and useful data have now been obtained for these objects (Martel et al. 1999; Laing & Bridle 2002; Hardcastle et al. 2002). Of these, here we highlight some of the data of interest to us, which can be used in the present

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work. Figures 5 and 6 show optical images of the region in the center of which is the galaxy NGC 383. The optical image shows a map 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.

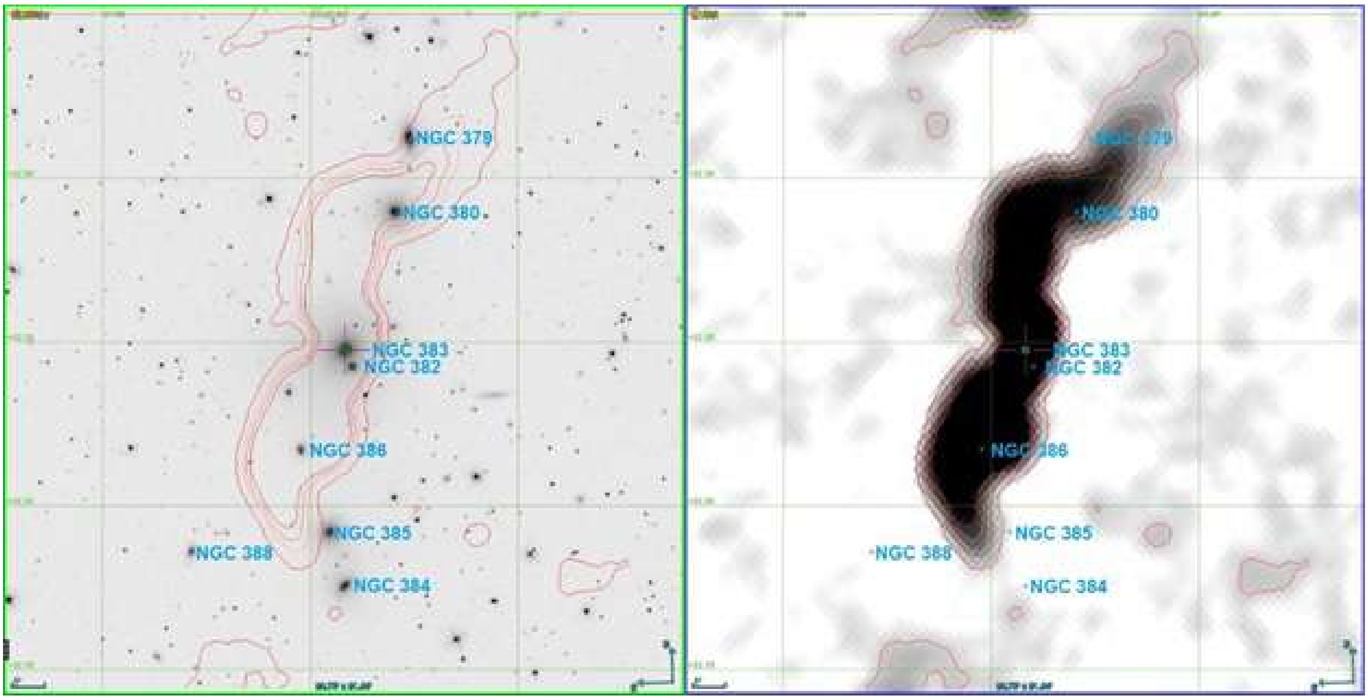

Figure 5. The region of a group of galaxies with the central object NGC 383 and radio source 3C31 of the FRI class at a frequency of 1400 MHz.

From the pictures it is clear that the galaxies NGC 380 and NGC 386 are located strictly on the same line but on different sides from the central galaxy NGC 383. The direction of this line coincides with the direction of the radio jets of 3C31. The difference of the red shift of the northern galaxy relative to the central galaxy is negative, and that of the southern galaxy is positive. Radio jet simulations (Laing & Bridle 2002) have shown that the direction of the 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. All this can be explained within the framework of the assumption that galaxies NGC 380 and NGC 386 move in the same direction as the radio jets. The calculations are presented in Table 1.

Table 1.

object	z	δz	δV km/s	D kpc	V_0 km/s	T Myr
NGC383	0.01700	0	0	0	0	-
NGC380	0.01476	-0.00224	-672	106.53	860.2	117
NGC386	0.01853	+0.00153	+459	78.12	587.5	126

The table shows that the galaxies NGC 380 and NGC 386 were near the galaxy NGC 383 about 120 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 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. 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).

4. The study of galactic clusters.

Evolution of galaxies in groups of galaxies. Another direction of work of our department is finding and studying the physical properties of galactic groups (Magtesyan 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 evolution corresponding to the concept of V. Ambartsumyan. Many

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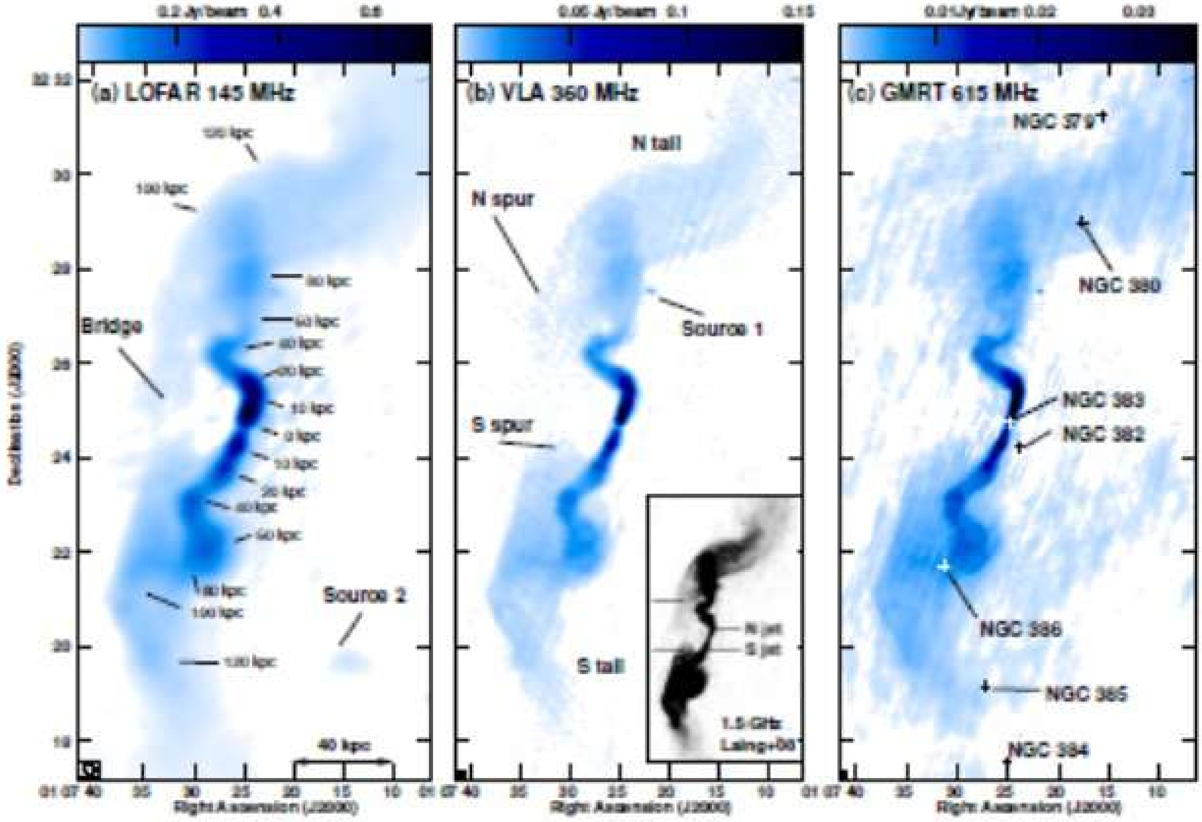

Figure 6. The region of a group of galaxies with the central object NGC 383 and radio source 3C31 of the FRI class at a frequency of 145, 360 and 615 MHz. (Heesen et al. 2018).

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 (Magtesyan and Movsesyan 1994). 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. Investigations in cosmology (about accelerating expansion of Universe).

It was shown that in the basis of the justification of the hypothesis of the expansion of the Universe with acceleration, and later in the confirmation of this hypothesis the same methodological error is present in the works. In all these works it is done standardization of luminosity of supernovae 1a type. It depends from the decay rate of the luminosity after the luminosity maximum of the supernova and from the color index of the star at its maximum brightness. These parameters according to the rule accepted by all authors should not depend on the redshift of the stars. Otherwise, we will artificially introduce the evolution of luminosity. However, our studies show that in estimated luminosities in all known samples of supernova type 1a stars the standardization parameters depend too strongly on redshift. It makes unacceptable such kind of standardization of supernovae luminosity. Such an approach removes the true evolution of supernova luminosity, having the effect of opposite direction. Therefore, the hypothesis of the accelerated expansion of the Universe is a consequence of the wrong estimate of the luminosity of supernovae. It means that the universe is expanding with deceleration. The dark energy theory is not applicable (Abraham Mahtesyanet all. 2022).

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6. Magnetic fields of galaxies.

6.1. A Biermann battery effect as a possible mechanism of formation of magnetic fields in active galaxies.

The essence of Birman's mechanism lies in the fact that the electrons and protons participating in the gas movement in radial directions, having a large difference in mass, interact with the particles of the rotating medium at different times and in different places. As a result, electrons and protons acquire different rotational speed components, a circular electric current and a dipole magnetic field is generated.

It was shown that in the active galaxies, whose central regions have strong outflow of ionized gas into the rotating medium, the Birman (battery mechanism) effect works, thanks to which a magnetic field is generated from scratch in the medium, which can later be strengthened by the so-called dynamo mechanisms (Mikhailov, E. A.; Andreasyan, R. R 2021).

This mechanism also works in case of accretion of matter on the nuclei of galaxies. In our recent work, the effectiveness of the Birman mechanism in accretion discs was studied. It is necessary to solve an integral equation of the second order, if the interaction of the generated magnetic fields on the movement of charged particles is considered. It has been shown that the generated fields are quite significant and can play an important role in the further evolution of magnetic fields in accretion disks (Andreasyan, R. R.; Marchevsky, I. K.; Mikhailov, E. A. 2024).

6.2. A study of the magnetic field of our Galaxy using the Faraday rotation data of pulsars and extragalactic radio sources.

When polarized radiation passes through a magneto-ionic medium, the plane of polarization rotates. In radio astronomy, this rotation is characterized by the so-called Rotation Measure (RM). Such data are known for about 40,000 extragalactic radio sources and more than 2,300 pulsars. For pulsars, data are also known on the Dispersion Measures, which are caused by the phenomenon of signal delay of a given pulse at different frequencies. These data are directly derived from observations of pulsars. Theoretically they are expressed by the electron density ne in the interstellar medium through which the polarized radio emission of the pulsar passes and the projection of the magnetic field B_L (in Gauss) in this medium, using the following formulas:

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

$$t_2 - t_1 = (2\pi e^2/m)(1/\omega_2^2 - 1/\omega_1^2)DM \quad (2)$$

$$DM = \int n_e dL \quad (3)$$

$d\Psi$ - 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 pulsar 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 2 together with formula 1 makes possible to determine the average component of the interstellar magnetic field $[B_L]$ on the line of sight in microgauss (μG).

$$< B_L >= (1/\alpha)(RM)/(DM) = 1.23(RM)/(DM) \quad (4)$$

$$B_l(R)n_e(R, l) = (1/\alpha)d(RM)/d(R) \quad (5)$$

$$B_l(DM) = (1/\alpha)d(RM)/d(DM) \quad (6)$$

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Using formulas 4 and observational data, it is possible to study the direction and magnitude of the average magnetic field in the direction of the pulsar, and formulas 5 and 6, with sufficient data, make it possible to construct a map of the magnetic field of the Galaxy.

Faraday rotation data on 336 pulsars and more than 2000 extragalactic radio sources are used in a detailed study of the magnetic field in the direction of galactic longitude $40^o < l < 70^o$, including the Sagittarius spiral arm region. The highly regular magnetic field in the northern hemisphere of the galaxy is directed to the Sun, when the magnetic field of southern hemisphere is directed from the Sun. This is clear from the study of the distribution of rotation measures of pulsars as well as from these data of extragalactic radio sources. We propose that the Sagittarius spiral arm lies mainly to the north of the Galactic plane, while the magnetic field with opposite direction below this plane is the field of the halo of the southern hemisphere of the Galaxy.

This result is consistent with the model of a two-component magnetic field of the galaxy proposed in (Andreasyan and Makarov 1989)

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