ВАК 2024 MODERN ASTRONOMY: FROM THE EARLY UNIVERSE TO EXOPLANETS AND BLACK HOLES
300 years Russian Academy of Sciences

Supermassive binary black holes in the centers of galaxies and prospects for their observation

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Abstract. A list of candidates for supermassive binary black holes has been compiled based on an analysis of available data regarding variability in the optical range and the shape of the emission spectrum. An artificial neural network has been constructed to estimate the radiation flux at a frequency of 240 GHz. For the candidates of supermassive binary black holes where the network construction process was feasible, the criterion for the possibility of observing the source at the Millimetron Space Observatory has been tested. The study presents its results in a table that lists 17 candidates for supermassive binary black holes.

Keywords: quasars: supermassive black holes; techniques: interferometric

DOI: 10.26119/VAK2024.033

1 Introduction

It is believed that a supermassive black hole (SMBH) exists in the central region of virtually every massive galaxy. In turn, according to current understanding, the gravitationally bound halo of dark matter, which is the dynamically dominant component of any galaxy, experiences multiple mergers with smaller-mass halos during its evolution. Numerical simulations can also highlight a major merger event, during which the halo interacts with another halo of similar mass. This suggests that for some period, multiple SMBHs should be present within galaxies, leading to the existence of supermassive binary black holes (SMBBHs).

2 Search for SMBBHs

One of the main directions in the search for SMBBHs is the analysis of the optical variability of active galactic nuclei, primarily quasars. For instance, in Graham et al. (2015), the Catalina Real-time Transient Survey (CRTS) catalog, comprising 243 500 spectroscopically confirmed quasars, was analyzed. As a result of the search, 111 objects exhibiting signs of variability, with periods on the order of one year, were selected as candidates for SMBBHs.

A search for SMBBH candidates was also conducted in Charisi et al. (2016) through an analysis of the Palomar Transient Factory (PTF) catalog, which includes 35 383 spectroscopically confirmed quasars. The analysis of this catalog identified 50 quasars with statistically significant periodicity. Additionally, combining data with the CRTS catalog contributed 33 new sources to the list of SMBBH candidates. Together with OJ 287, the famous candidate for SMBBH, this totals 145 candidates for SMBBHs.

3 Simulation of the Spectra of the SMBBH candidates

For the purposes of the study, among the 145 known candidates for SMBBHs, those were selected for which data on fluxes at frequencies higher and lower than 240 GHz were available. This resulted in a total of 17 objects. Additionally, 7 more DSMBH candidates found in other publications were added to this list.

To model the radiation flux at a frequency of 240 GHz, an artificial neural network was developed. The input data for this network consisted of the observed frequencies, and the output included the radiation flux densities at those frequencies. Initially, the model was trained on the available public data (see NASA/IPAC Extragalactic Database (NED)). Then, the trained network determined the radiation flux density at the frequencies of interest. The programming language used was Python, and the machine learning library was TensorFlow.

An example of the modeling for one of the 24 sources is shown in Fig. 1.

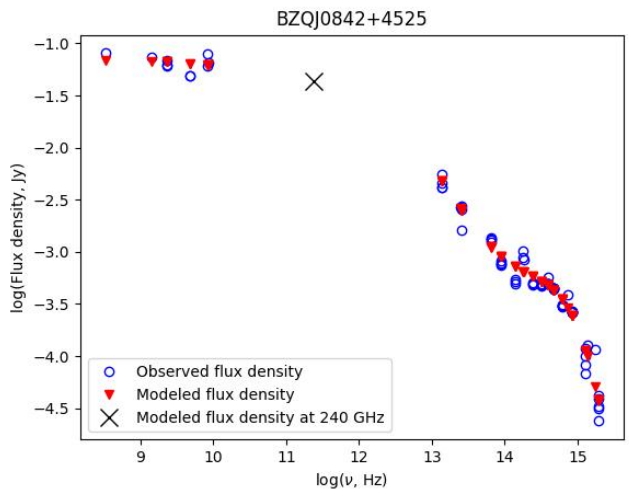

Fig. 1. Modeled spectra of BZQ J0842+4525.

4 SMBBHs and space-VLBI

The small angular sizes of supermassive black holes (SMBHs) make space-ground VLBI observations in the millimeter and submillimeter range particularly important, as noted by Ivanov et al. (2019). In the same work, a criterion for selecting sources for observations at the Millimetron Space Observatory (MSO) was formulated. This criterion was modified by the authors for the purposes of this study, utilizing a frequency of 240 GHz as the primary frequency.

Table 1 summarizes the results of the analysis conducted. It presents the sources for which there is a range of baseline projections where the amplitude of the visibility function is above a threshold value, which is 6.45 mJy for 240 GHz for MSO. Table 1 provides the source name, its right ascension α and declination δ for epoch J2000, the flux F_{ANN} obtained from modeling, expressed in Jansky (Jy), the angular size of the shadow of the more massive component of the SMBBH system θ (defined as in Mikheeva et al. 2019), expressed in arc microseconds, and the angular separation between the components of the binary system d, also expressed in arc microseconds.

Table 1. Candidates for supermassive binary black holes that meet the selection criteria.

Source	α, h m s	δ, ^{o} $'$ $''$	$F_{\rm ANN}$, Jy	θ, μs	d, μs
CSO 0402+379	04 05 09.3	+38 03 32.2	0.043	0.068	6580
FBQS J081740.1+232731	08 17 40.2	+23 27 32.0	0.027	0.220	1.375
BZQ J0842+4525	08 42 15.3	+45 25 45.0	0.050	0.173	1.385
OJ 287	08 54 48.9	+20 06 30.6	2.72	1.935	11.96
MCG +11-11-032	08 55 12.5	+64 23 45.6	0.23	0.067	4.82
SBS 0924+606B	09 28 37.98	+60 25 21.0	0.019	0.087	9.69
SDSS J102349.38+522151.2	10 23 49.5	+52 21 51.8	0.027	0.237	1.717
SDSS J124044.49+231045.8	12 40 44.5	+23 10 46.1	0.014	0.058	1.072
BZQ J1305-1033	13 05 33.0	−10 33 19.1	0.37	0.035	1.794
SDSS J132103.41+123748.2	13 21 03.4	+12 37 48.1	0.016	0.055	1.0935
SDSS J133654.44+171040.3	13 36 54.4	+17 10 40.8	0.032	0.101	0.935
3C 298.0	14 19 08.2	+06 28 35.1	0.022	0.213	1.498
TEX 1428+370	14 30 40.6	+36 49 03.9	0.14	0.025	0.319
SDSS J150243.09+111557.3	15 02 43.1	+11 15 57.3	0.014	0.01	25500
FBQS J150911.2+215508	15 09 11.2	+21 55 08.8	0.0094	0.029	0.411
PG 1553+113	15 55 43.0	+11 11 24.4	0.06	0.01	0.73
PKS 2203-215	22 06 41.4	−21 19 40.5	0.17	0.059	0.602

5 Conclusion

The results of the conducted study are presented in Table 1. The list includes 17 candidates for SMBBHs, whose duality may be confirmed through observations with a space-based interferometer that has an orbit and sensitivity at a frequency of 240 GHz, similar to the planned Millimetron Space Observatory.

The table with SMBBH candidates may be extended after additional observations or studies, as the main reason why the list is much shorter than the initial number of SMBBH candidates is the lack of observational data around a frequency of 240 GHz (at which the modeling was carried out), mainly at lower frequencies.

References

Charisi M., Bartos I., Haiman Z., et al., 2016, MNRAS, 463, p. 2145
Graham M., Djorgovski S., Stern D., et al., 2015, MNRAS, 453, p. 1562
Ivanov P., Mikheeva E., Lukash V., et al., 2019, Phys. Usp., 62, p. 423
Mikheeva E., Lukash V., Repin S., et al., 2019, Astronomy Reports, 63, p. 343