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

Measurements of the flux densities and variability of the standard flux scale "Artificial Moon" sources on time scales of 1–8.5 years

V. Ivanov, A. Ipatov, I. Rakhimov, and T. Andreeva

Institute of Applied Astronomy of the Russian Academy of Sciences, St. Petersburg, 191187, Russia

Abstract. We present flux density measurements for the standard radio sources of the "Artificial Moon" (AM) absolute flux scale during the time interval of 2017.5–2024.0 at wavelengths $\lambda = 3.5$ and 6.2 cm. The standard sources are weakly variable, and maintaining the accuracy of the scale requires regularly recurring calibrations. Currently, the RT-32 radio telescope at the Svetloe Observatory of the Institute of Applied Astronomy of the Russian Academy of Sciences (IAA RAS) monitors the AM flux scale standard sources to study their variability and maintain the accuracy of the scale. We determined the flux densities of the AM flux scale calibrators at two wavelengths during the time interval of 2017.5–2024.0. The measurement errors for both wavelengths did not exceed ±2%, the measurement data were averaged over time intervals of 1 year at the average epochs 2019.0, 2022.0, and 2023.0. A comparison of the standard source flux densities S for the epochs 2019.0, 2022.0, and 2023.0 with each other as well as with the flux densities S_0 at the epoch 2015.5 has shown that at time intervals of more than 1 year, there exists variation in the standard source flux densities that exceeds the standard deviations σ and the established flux scale error limits of ±3%. We conclude that it is necessary to recalibrate the standard sources at least every 2 years to maintain the accuracy of the flux scale.

Keywords: methods: data analysis, observational; telescopes

DOI: 10.26119/VAK2024.167

1 The measurements and their comparison

The flux density measurements for the standard radio sources of the "Artificial Moon" (AM) flux scale (Ivanov et al. 2018) during the time interval of 2017.5–2024.0 at wavelengths $\lambda = 3.5$ and 6.2 cm are presented.

The AM flux scale standards are strong extragalactic sources with minimum, among the others, variation of the radio emission over time. However, the observations have shown the presence of a variable component in almost all the sources, which may be a consequence of variation in the short-range components contributing to the total flux.

The standard sources are weakly variable, and maintaining the accuracy of the scale requires regular calibrations. The flux densities of the AM flux scale calibrators are recurrently measured with the RT-32 radio telescope at the Svetloe Observatory of the IAA RAS to study their variability and maintain the accuracy of the scale. In a repeating cycle, the flux densities of the AM standards 3C48, 3C123, 3C138, 3C147, 3C161, 3C196, 3C218, 3C274, 3C286, 3C348, and 3C353 are measured relative to the stable source 3C295, which serves as the primary standard. A description of the RT-32 full-circle parabolic radio telescope with a mirror diameter $D = 32$ m is given in Rakhimov et al. (2001); Finkelshtein (2001); Finkelshtein et al. (2002). The measurements are carried out according to the standard technique adopted for the radio telescopes of the Quasar system. The data processing is described in Ivanov et al. (2018). The measurement results are shown in Table 1.

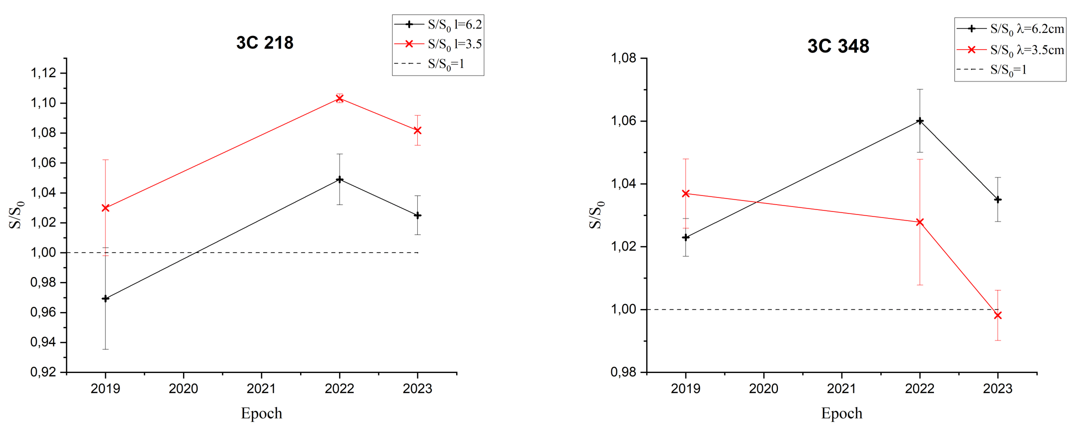

Fig. 1. Temporal dependence of the flux density ratio S/S_0 for 3C218 and 3C348 between the epochs 2015.5–2019.0, 2022.0, and 2023.0.

Table 1. Standards fluxes over time and comparison with the 2015.5 epoch. S and σ are the flux density and its standard deviation, S_0 is the flux density at the epoch 2015.5.

Source	Epoch	$\lambda = 6.2$ cm				$\lambda = 3.5$ cm			
		S, Jy	σ, Jy	S/S_0	σ/S	S, Jy	σ, Jy	S/S_0	σ/S
3C48	2015.5	5.08				3.18			
	2019.0	5.12	0.15	1.01	0.03	3.37	0.07	1.06	0.02
	2022.0	5.0	0.05	0.98	0.01	3.21	1.01	1.01	0.04
	2023.0	4.95	0.06	0.97	0.01	3.28	1.03	1.03	0.04
3C123	2015.5	14.53				9.37			
	2019.0	14.79	0.12	1.02	0.01	9.42	0.09	1.01	0.01
	2022.0	14.87	0.14	1.02	0.01	9.38	0.12	1.00	0.01
	2023.0	14.85	0.19	1.03	0.01	9.18	0.08	0.98	0.01
3C138	2015.5	3.81				2.93			
	2019.0	3.68	0.13	0.97	0.03	3.00	0.00	1.02	0.00
	2022.0	3.77	0.04	0.99	0.01	2.88	0.02	0.98	0.01
	2023.0	3.80	0.04	1.00	0.01	2.92	0.04	1.00	0.01
3C147	2015.5	7.13				4.73			
	2019.0	7.30	0.14	1.02	0.02	4.98	0.11	1.05	0.02
	2022.0	7.17	0.07	1.01	0.01	4.72	0.04	1.00	0.01
	2023.0	7.14	0.03	1.00	0.00	4.66	0.05	0.99	0.01
3C161	2015.5	6.03				3.94			
	2019.0	6.05	0.06	1.00	0.01	3.65	0.09	0.93	0.02
	2022.0	6.24	0.04	1.03	0.01	3.82	0.22	0.97	0.06
	2023.0	6.07	0.07	1.01	0.01	3.91	0.03	0.99	0.01
3C196	2015.5	3.98				2.37			
	2019.0	3.95	0.03	0.99	0.01	2.37	0.03	1.00	0.01
	2022.0	3.88	0.01	0.97	0.00	2.34	0.02	0.99	0.09
	2023.0	3.83	0.02	0.96	0.01	2.34	0.01	0.99	0.01
3C218	2015.5	11.76				7.02			
	2019.0	11.40	0.39	0.97	0.03	7.23	0.23	1.03	0.03
	2022.0	12.34	0.20	1.05	0.02	7.74	0.02	1.10	0.00
	2023.0	12.06	0.16	1.02	0.01	7.59	0.08	1.08	0.01
3C274	2015.5	64.56				44.33			
	2019.0	62.90	0.29	0.97	0.00				
	2022.0	63.06	0.75	0.98	0.01	43.17	0.66	0.97	0.01
	2023.0	63.69	0.29	0.99	0.00	44.30	0.26	1.00	0.01
3C286	2015.5	6.91				5.19			
	2019.0	6.95	0.06	1.01	0.01	5.24	0.08	1.01	0.01
	2022.0	6.41	0.11	0.93	0.02	5.03	0.10	0.97	0.02
	2023.0	6.62	0.07	0.96	0.01	4.96	0.04	0.96	0.01
3C348	2015.5	11.28				6.41			
	2019.0	11.54	0.06	1.02	0.01	6.64	0.07	1.04	0.01
	2022.0	11.96	0.12	1.06	0.01	6.59	0.13	1.03	0.02
	2023.0	11.67	0.08	1.03	0.01	6.40	0.05	1.00	0.01
3C348	2015.5	19.84				13.49			
	2019.0	20.79	0.73	1.05	0.03	13.84	0.22	1.03	0.02
	2022.0	21.19	0.11	1.07	0.00	13.80	0.52	1.02	0.04
	2023.0	20.67	0.47	1.04	0.02	13.53	0.35	1.00	0.03

A comparison of the data in Table 1 for the epochs 2015.5, 2019.0, 2022.0 and 2023.0 shows (Fig. 1) that during the time interval of 2015.5–2024.0, at both wavelengths we observe variation in the flux densities of the standard sources, which significantly exceeds the standard deviations σ. For the data between 2022.0 and 2023.0, separated by an interval $\Delta t = 1$ year, there are no differences significantly greater than σ. For $\Delta t > 1$ year, the differences in some cases are significant.

The comparison of the flux density measurements for the AM flux scale standards at different epochs leads to the conclusion that it is necessary to recalibrate the standard sources at least every 2 years to maintain the accuracy of the flux scale at a level of $\pm3\%$.

References

Finkelshtein A., 2001, Nauka v Rossii, 5, p. 20

Finkelshtein A., Ipatov A., Smolensev S., 2002, Proc. Fourth APSGP WorkShop, ed. H. Cheng, Q. Zhihan, p. 47

Ivanov V.P., Ipatov A.V., Rakhimov I.A., et al., 2018, Astronomy Reports, 62, p. 574

Rakhimov I., Akhmedov Sh., Zborovsky A., et al., 2001, All-Russian Astronomical Conference, Conference abstracts, p. 152