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AGN intra-day and inter-day variability studies with VIRAC radio telescopes

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Since year 2017, radio telescopes of Ventspils International Radio Astronomy Centre (VIRAC) are used to study intra-day and inter-day variability of various types of active galactic nuclei (AGN). These studies are based on a generalization of the results of a 40-year monitoring of extragalactic radio sources flux conducted by Michigan Radio Astronomy Observatory in the USA using wavelet and Fourier analysis performed at Odessa Observatory of the Radio Astronomy Institute of the National Academy of Sciences (NAS) of Ukraine. On this basis, a catalogue for the properties of the variability of extragalactic radio sources was created. The extension of the temporal spectrum of flux changes to inter-diurnal and diurnal scales is carried out with the help of VIRAC radio telescopes RT-32 and RT-16 respectively with 32- and 16-meter antennas. The intra-day variability of the calibration source 3C295 (Type 2 Seyfert Galaxy) is detected and preliminary results presented in the paper for discussion. Several other radio sources (3C 273, 3C 454.3, OJ 287, BL Lac) are suspected to have variability of such type and are scheduled for monitoring observations as well. The paper discusses possibility of observing these promising objects during VLBI sessions by EVN and parallel long-term total flux monitoring with VIRAC antennas. The temporal changes in flux linked with VLBI maps opens opportunity to determine the nature of the physical processes that form fast flux changes of various types of active galactic nuclei.

Keywords: VIRAC, radio astronomy, AGN monitoring, intra-day and inter-day variability.

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1. Introduction

Variability of the AGN in radio range on time scales of several days and less than a day (IDV) is one of the most interesting and intriguing appearances of their activity. Despite the fact that IDV are often explained by scintillation of radio sources in the interstellar medium [1], many facts of correlated flux variations between radio frequencies, as well as between radio and optical observations suggest presence of internal activity appearances in radio sources that form IDV [2, 3]. While these processes are not very clear and various proposed explanations are a topic for scientific discussions. In addition, existing IDV observations are often short and episodic. On this basis, in April 2017, Ventspils International Radio Astronomy Centre (VIRAC) together with Radio Astronomy Institute National Academy of Sciences (NAS) of Ukraine, began to conduct a monitoring observation program to study intra-day and inter-day variability of bright active galactic nuclei (AGN) in the radio band. Until August 2018, 213 observation sessions of radio sources 3C 273, 3C 454.3 (quasars), OJ 287, BL Lac (BL Lacertae objects), 3C 295 (Type 2 Seyfert Galaxy) were performed by 16 *m* and 32 *m* radio telescopes of VIRAC at frequencies 5, 6.1, 6.7 and 8.4 *GHz*. Radio telescopes and receiving equipment were adapted for high-precision IDV observations and a number of technical problems that introduced distortions in the observations were solved. The obtained preliminary results of the study of quasi-periodic variations in flux density of the studied AGNs are presented in this article.

2. Method of observations

The team of VIRAC operates two radio telescopes with diameters of 16 and 32 meters. They are equipped with wideband cryogenic receivers with four working frequencies: 5, 6.1, 6.7 and 8.4 *GHz*. Currently, additional equipment is being set up on 32 *m* radio telescope to perform observations at 1.6 *GHz* band. The observations for April-June 2017 were conducted at four frequencies: 5, 6.1, 6.7, 8.4 *GHz*. Later, the noisy 8.4 *GHz* band was excluded from the observations. To increase number of data points, from July 2017 6.1 *GHz* band was also excluded as well. Currently observations are carried out at frequencies 5 and 6.7 *GHz*.

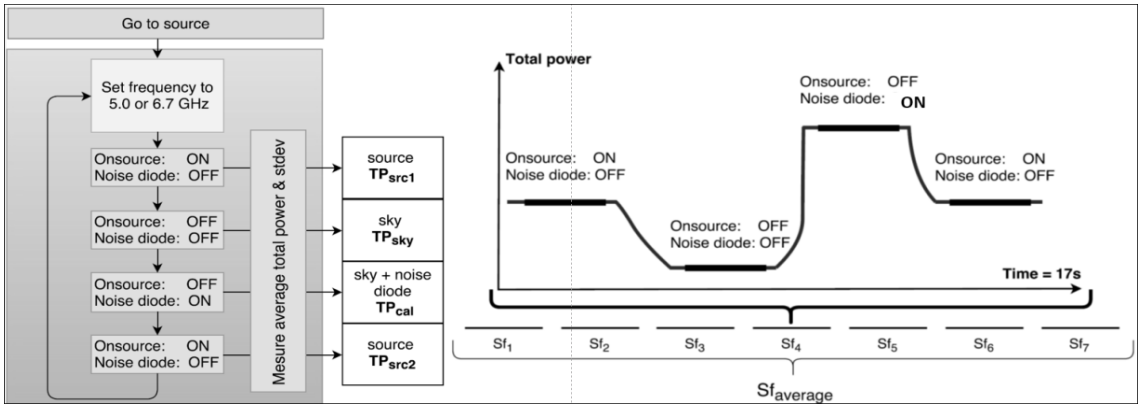

Figure: 1. Algorithm for measuring flux density when observing IDV with VIRAC radio telescopes.

To reduce the influence of receiver gain variations and calibrate arbitrary power counts to antenna temperature in Kelvins, four calibration phases are used during measurement of each point as illustrated in Figure 1: during TP_{src1} and TP_{src2} phases, beam points on-source, TP_{sky} is measurement with beam pointing off-source and TP_{cal} is also off-source measurement, but with calibration diode turned on. Obtained antenna temperature values are then converted to flux

density with help of antenna elevation dependent gain curve equation, which is updated regularly by observing calibration sources 3C196, 3C286 and 3C123. It takes about 17 seconds to get one sample of flux density; every 7 samples are averaged to reduce noise. The technique of observations and study of parameters of radio telescopes are described in more detail in article [4].

3. Methods of observations data processing

The IDV study program began with observations of the radio source 3C 295 (Type 2 Seyfert Galaxy). This interesting and little-studied radio source is located in a large cluster of galaxies and is surrounded by an extensive gas cloud emitting in the X-Ray range [5]. Usually 3C 295 is used as a calibration source and its long-term average flux changes are small, according to UMRAO about 1 *Jy* at frequencies 4.8, 8, 14.5 *GHz* [6]. The article [7] notes possible presence of 3C 295 microvariability with quasi-periods of about 36 and 73 days. In article [8] characteristic times of flow variation at frequencies of 2 and 8 *GHz* are estimated at approximately 10 and 16 days. Figure 2 shows example results of flux changes for radio sources OJ 287, 3C 273, 3C 295 obtained from observations by RT-16 VIRAC at frequencies 5 and 6.7 *GHz*. A fast calculation method was used to determine periodograms for non-uniform time series using FFT, described in detail in paper [9]. Preliminarily, the data was smoothed by a moving average. Differentiated data was used to determine minimum time scale for the flux changes. Differentiation suppresses slow flux variations and linear trends, enhancing fast ones.

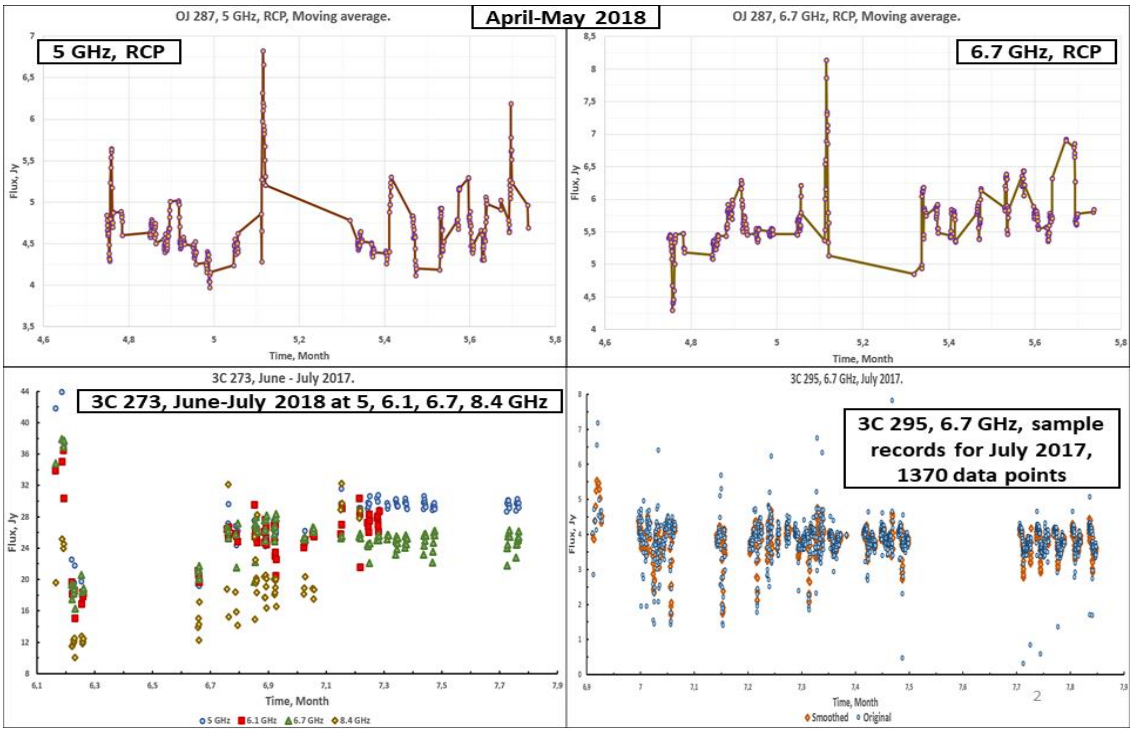

Figure: 2. The upper part of the figure is smoothed by moving average (10-point half-size of smoothing window) and shows source OJ 287 at frequencies 5 and 6.7 *GHz*. A powerful simultaneous burst can be seen. At bottom of the figure, records for sources 3C 273 and 3C 295 are shown. For the source 3C 273, there is a day-to-day trend of increasing flux for two months at 4 frequencies.

4. Results

From April 2017 to the present time, a program of observing active galactic nuclei has been conducted by radio telescopes of VIRAC (Latvia) in order to study the intra-day and inter-day variability of radio emission at frequencies 5 and 6.7 *GHz*. The data is smoothed by moving average and filtered from interference. In the April - May 2018 observation session, the presence quasi-period of ≈4.8 hours was determined for source 3C 295 at frequency of 5 *GHz*. This is in good agreement with ≈4.5-hour period found earlier during the session from June - July 2017. Subsequently, further observations will be made to confirm it. When analyzing day-to-day variability in the April-May 2018 session at frequencies 5 and 6.7 *GHz* the source 3C 295 presumably appears to have a long-term period of ≈3 days. It is also probably to have a longer period of ≈14 - 19 days at both frequencies. In the session June – July 2017, periods of ≈3 days and ≈10 - 11 days were determined, which is close to values obtained for the session April – May 2018. Changes in radio emission flux density for the quasar 3C 454.3 and the BL Lac object OJ 287 demonstrate significant and rapid fluctuations. However, presence of large gaps in the data and a small number of observation points do not yet allow to confidently assess the reliability of periods of flux changes. There may be a period of ≈65 hours (2.7 days) for the OJ 287 in the July – August 2018 session at a frequency 5 *GHz*. Also, for the sources 3C 273 and 3C 454.3, trend changes of high amplitude flux variations were observed in each observation session. In the April – May 2018 session, simultaneous burst at 5 and 6.7 *GHz* were noted for the source 3C 454.3. In this regard, in further implementation of the monitoring program, more attention will be paid to observations of radio sources 3C 273, 3C 454.3 and OJ 287 at different frequencies. This will allow to accumulate a sufficient amount of observations to reliably estimate the periods of flux density changes.

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References

[1] J. Dennett-Thorpe, A. G. de Bruyn. *Interstellar scintillation as the origin of the rapid radio variability of the quasar J1819+3845.* Nature, (*2002*), 415, 57-60.

[2] A. Witzel, D. Heeschen, C. Schalinski et al. *Kurzzeit-Variabilität extragalaktischer Radioquellen.* Mitt. Astron. Ges. (1986), 65, 239–241.

[3] S.J. Wagner. Multi-Frequency *Studies of Intrinsic Intraday Variability.* Astrophysics and Space Science, (*2001*), 278 (1-2), 105-111.

[4] M. Bleiders, V. Bezrukovs, and A. Orbidans. *Performance evaluation of Irbene RT-16 radio telescope receiving system.* Latvian J. Phys. Techn. Sci. (2017), 54 (6), 42-53.

[5] S.W. Allen, G.B. Taylor, P.E.J. Nulsen et al. *Chandra X-ray observations of the 3C 295 cluster core*., Mon. Not. R. Astron. Soc., (2001) 324 (4), 842-858.

[6] M.F. Aller, H.D. Aller, P.A. Hughes. *Pearson Readhead Survey Sources II: The Longterm Centimeter-band Total Flux and Linear Polarization Properties of a Complete Radio Sample*. Astrophys. J., (2003), 586 (1), 33-52.

[7] J.H. Fan, Y. Liu, Y.H. Yuan et al. *Radio variability properties for radio sources*. Astron. Astrophys. (2007), 462 (2), 547-552.

[8] B.J. Rickett, T.J.W. Lazio, F.D. Ghigo. *Interstellar scintillation observations of 146 extragalactic radio sources*., Astrophys. J. Suppl. Ser., (2006) 165, 439-460.

[9] W.H. Press, G.B. Rybicki. *Fast algorithm for spectral analysis of unevenly sampled data*. Astrophys. J., (1989), 338, 277-280.