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Observation of intra-day variability of extragalactic radio sources on IAA antennas

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The review describes the project of investigation of IDV with radio telescopes RT-32 at IAA Badary (Bd), Zelenchukskaya (Zc) and Svetloe (Sv) observatories. The project was started in 2003 and still ongoing.

In 2016 a VLBI observations of IDV sources was started with three RT-32 and two new RT-13 (Bv, Zv) on Badary and Zelenchukskaya observatories.

Purpose: search for IDV and determination of its parameters.

Observations: Each experiment consists of the sets of scans on reference and IDV sources:

<<<	Ref 30m	IDV 60m	Ref 30m	IDV 60m	Ref 30m	>>>

Observations was carried out in semi-automatic mode under MarkIV Field System software *(that is used for VLBI)* with help of the extra complex of software *(that was developed in IAA for SD).*

Nineteen sources was observed at 3.5 and 6.2 cm:

N	ID	RA2000 DE2000	N	ID	RA2000 DE2000
1	J1819+3845	18:19:27 +38:45:01	11	J1504+1029	15:04:25 +10:29:39
2	J0527+0331	05:27:33 +03:31:32	12	J2253+1608	22:53:58 +16:08:54
3	J0721+0406	07:21:24 +04:06:44	13	J1104+38	11:04:27 +38:12:32
4	J1728+0427	17:28:25 +04:27:05	14	J0309+1029	03:09:04 +10:29:16
5	J0449+1121	04:49:08 +11:21:29	15	J0530+1331	05:30:56 +13:31:55
6	J1347+1217	13:47:33 +12:17:24	16	J1603+1105	16:03:42 +11:05:49
7	J2123+0535	21:23:45 +05:35:22	17	J1756+1553	17:56:34 +15:53:44
8	J0721+7121	07:21:53 +71:20:37	18	J1728+1215	17:28:07 +12:15:39
9	J0211+1051	02:11:13 +10:51:35	19	J0238+1636	02:38:39 +16:36:59
10	J1159+2914	11:59:32 +29:14:44			

Reduction: during the reduction of the data, we used a robust method for determining the zero-flux level and a method for optimal filtration. We used the Fisher criterion to filter out data corrupted by poor weather conditions or man-made interference. The procedure used for the observations and processing are described in detail in [1].

Statistical analysis:

Chi-Square-test to check whether a source is variable or not:

$$\chi_r^2=\frac{1}{N-1}\sum_{i=1}^{N}\left(\frac{S_i-\langle S\rangle}{\Delta S_i}\right)^2$$

N – number of measurements
S_i & ΔS_i – mean flux density and its error for the individual set of scans
<S> – mean flux density for full experiment of N sets.

Only sources for which this probability is ≤0.1% are considered to be variable.

Modulation index to estimate the strength of the observed variation:

m [%] = 100 ΔS / <S>

ΔS & S – standard deviation & mean flux density for full experiment of N sets.

Variable component flux density :

$$S_{var}=\sqrt{\frac{(N-1)(\chi^2-1)}{\sum_{i=1}^{N}\Delta S_i^{-2}}}$$ [2]

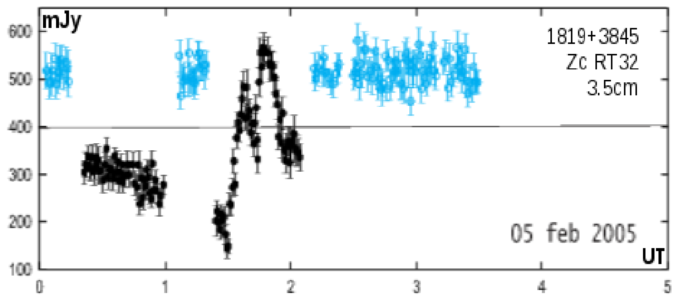
Structure function of the first-order (SF) for to rough estimation of the variability timescale τ_{sf}:

$$D(\tau)=\langle[S(t)-S(t+\tau)]^2\rangle_t$$ *τ – temporal lag*

The variability timescales were determined from the form of the SF. Above the level of the instrumental noise, the SF grows as a power law until it reaches a saturation level. The intersection of the power-law part with the saturation level yields the timescale τ_{sf} .

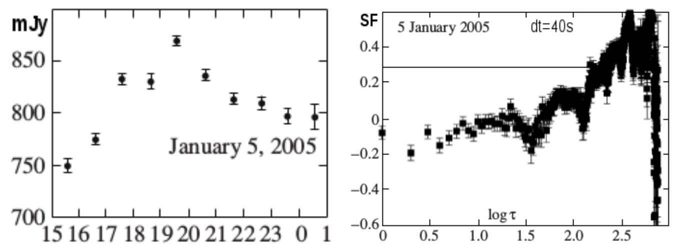
Autocorrelation function (ACF) to determine more accurately the variability timescale – time delay corresponding to the first ACF minimum τ_{acf} corresponds to the time delay where the SF reaches its maximum.

2003-2005 = Tests on J1819+3845. First stage result: IAA antennas are usable for observation of IDV. We continue to searching IDV in sources with flat-spectrum mainly from RATAN-600 Surveys.

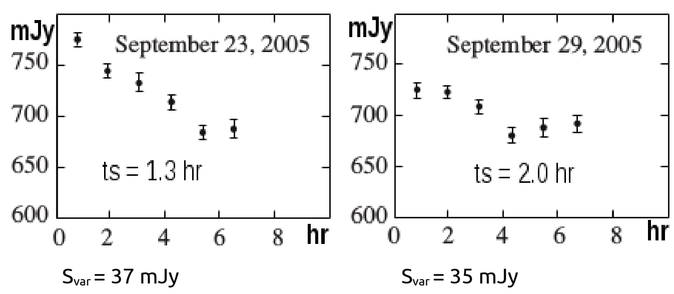


Results = J0527+0331. 24 experiments at 3.5cm with Zc RT-32 during 2004/07-2007/03. IDV was detected in period 2005/01-04 on 8 sessions when the source activity was near its maximum. [1]

S_{var}=100mJy, IDV time-scale τ_{sf} =4.3-4.5hr. D_{var}≥160 => origin of these IDV is most likely external.

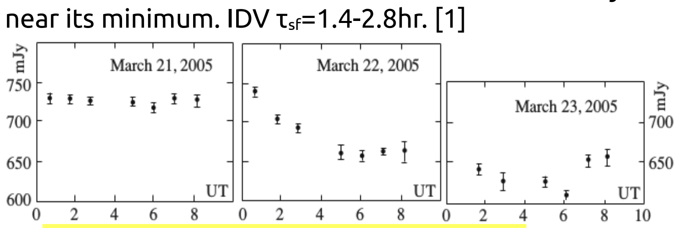


Results = J0721+0406. 18 experiments at 3.5cm with Zc RT-32 during 2005/01-2006/01. A weak IDV was detected on 9 sessions when the source activity was near its minimum. [1]

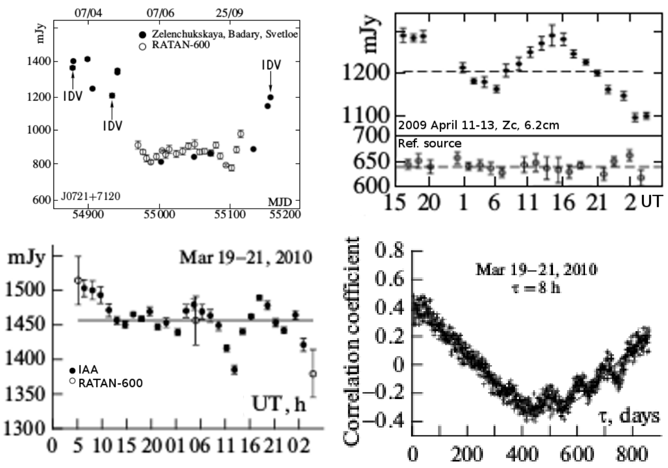


S_{var} = 37 mJy S_{var} = 35 mJy

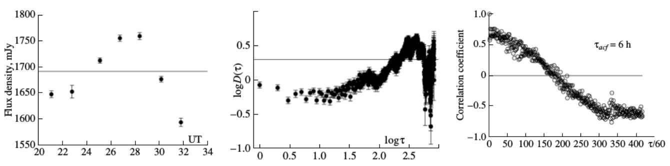
Results = J1728+0427. 8 experiments at 3.5cm with Zc RT-32 during 2005/03-09 and 2006/01. IDV was detected on 3 sessions when the source activity was near its minimum. IDV τ_{sf}=1.4-2.8hr. [1]



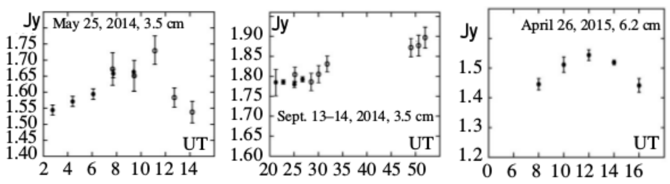
Results = J0721+7120 (S5 0716+714). 13 exp-s at 6.2cm with Bd, Sv and Zc RT-32 during 2009/02-11; 16 exp-s at 6.2cm with Zc RT-32 during 2010/03-10; and 5 exp-s at 3.5cm with Zc RT-32 during 2010/04-06. IDV was detected on 8 sessions near maximum of the source activity. IDV τ_{sf}=10-12hr and τ_{acf}=8-16hr. [3, 4]



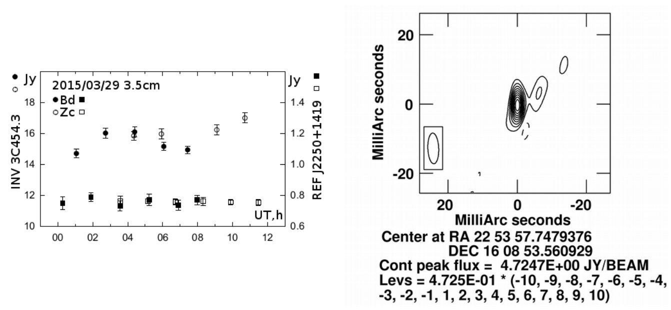
Results = J1159+2914 (S5 1156+295). 28 exp-s at 3.5&6.2cm with Bd and Zc RT-32 during 2010/11-2013/05. IDV was detected in 2012/11/10-11 at 6.2cm. S_{var}=126mJy, IDV τ_{acf} =6hr. [5]



Results = J0530+1331 (B0528+134). 38 experiments at 3.5&6.2cm with Bd and Zc RT-32 during 2014/05-2015/12. IDV was detected on 3 sessions when the source activity was near its minimum with low modulation indexes m~0.9-1.2, S_{var}=98-120mJy. [6]



Results = J2253+1608 (3C454.3). 80 experiments at 3.5&6.2cm with Bd and Zc RT-32 during 2014/06-2015/12 and still going on. IDV was detected on 10 sessions. Recently from the first QUASAR 5-station VLBI observation in July 2016 was obtained an image of 3C454.3 at 13cm. Data are under processing and analyzing. Results will be published in 2017.



Summary

In 2003-2015 on IAA antennas was made a number of regular SD observations on searching and monitoring of IDV at 19 extragalactic flat-spectrum radio sources. Our statistic shows that significant IDV is observed mainly at the maximum phases of the long-term variability of the sources.

References

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