Secular Decrease and Random Variations of Cassiopeia A at 151.5 and 927 MHz

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Summary. Long-term measurements of the radio flux density of Cassiopeia A relative to Cygnus A have been carried out at 927 and 151.5 MHz. It was found the following mean secular decrease rates of the radio emission of Cassiopeia A: $(0.72 \pm 0.03)\%\,\text{year}^{-1}$ at 927 MHz (for the period 1977–2002) and $(0.88 \pm 0.09)\%\,\text{year}^{-1}$ at 151.5 MHz (for the period 1980–2002). These values of the secular decrease rate obtained over the period of the last 25 years are substantially less than those of Baars et al. (1977). This indicates to the slowing down of Cassiopeia A radio emission secular decrease. In addition to this large scale time variation of Cassiopeia A flux density the measurements have also shown a small scale (a few years) time variations over the smooth secular decrease.

1 Introduction

The secular decrease rate $d = S^{-1}dS/dt$ of the radio emission of young supernova remnant Cassiopeia A was determined in many early investigations using relatively few measurements (sometimes only 2–3 measurements) of its flux density $S$ at different epochs. However, if we want to measure not only some mean $d$ over a long time interval but also to reveal some possible time variations of $S$, we have to make more measurements. In addition, measurements at a given frequency $\nu$ should be carried out using the same or rather similar radio telescopes and identical measurement procedures.

This report presents the results of long-term (1977–2002) measurements of the flux density of Cassiopeia A relative to that of Cygnus A at 927 and 151.5 MHz.

2 Measurements of the Cassiopeia A radio flux density relative to Cygnus A at 927 MHz

In the very beginning of August 2002 we carried out the measurements of the Cassiopeia A radio flux density relative to Cygnus A at the Radio Astronom-
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ical Observatory “Staraya Pustyn’” (geographical latitude 55°39′, longitude 2°54.5′) using 10-m radio telescope at 927 MHz. These measurements are an extension of the long-term ones initiated in 1977 [1–3]. Using one and the same radio telescope makes it possible to obtain a uniform observational material. The measurement method consisted as before of successive registration of Cassiopeia A and Cygnus A radio emission relative to definite reference areas. One record of Cygnus A had the following sequence of antenna pointings lasted totally 6 minutes: reference area – source – reference area (“off” – “on” – “off”). The sequence of the same duration for Cassiopeia A was the following: first reference area – source — second reference area (“off1” – “on” – “off2”). The reference areas for Cassiopeia A have the following coordinates: right ascension \(\alpha_{\text{off1}} = \alpha_{\text{CasA}} - 0^h40^m\), \(\alpha_{\text{off2}} = \alpha_{\text{CasA}} + 0^h40^m\), declination \(\delta_{\text{off1,2}} = \delta_{\text{CasA}}\), that one for Cygnus A has, respectively: \(\alpha_{\text{off}} = 20^h12^m\), \(\delta_{\text{off}} = 45°05'\) (coordinates for the epoch 1950.0). The radio emission of sources was registered at such time intervals when the elevation difference of Cassiopeia A and Cygnus A by its absolute value did not exceed 7° at an average elevation of both the sources 72°. These conditions define the time and duration (about 2 hours) of one session of measurements. As a result of two sessions we obtained the following ratio of Cassiopeia A and Cygnus A flux densities at 927 MHz:

\[
\left(\frac{S_{\text{CasA}}}{S_{\text{CygA}}}\right)_{927\text{MHz}} = 1.096 \pm 0.011 \text{ for the epoch 2002.58.}
\]

Figure 1 shows all values of \(\left(\frac{S_{\text{CasA}}}{S_{\text{CygA}}}\right)_{927\text{MHz}}\) for all years of measurements using RT-10 at 927 MHz [1–3] obtained from measured values by multiplying by 0.89 to take into account the difference of brightness temperatures in the direction of Cygnus A and its reference area.
3 Interferometric measurements of the Cassiopeia A radio flux density relative to Cygnus A at 151.5 MHz

In August – September 2002 we carried out the measurements of Cassiopeia A radio flux density relative to Cygnus A at the Radio Astronomical Observatory “Staraya Pustyn’” using the interferometer consisting of two 14-m radio telescopes at 151.5 MHz. One session of measurements consisted of a one hour record of Cygnus A fringes near the upper culmination, then that of Cassiopeia A near also the upper culmination and calibrations by the noise generator. For this interferometer with a base of 31λ both sources are practically point ones. By each measurement session we defined the amplitude ratio of fringes of Cassiopeia A and Cygnus A equal to the ratio of their flux densities. There were five measurement sessions. As a result we got:

\[(S_{\text{CasA}}/S_{\text{CygA}})_{151.5 \text{ MHz}} = 0.91 \pm 0.01\] for the epoch 2002.67.

Figure 2 shows the values of \((S_{\text{CasA}}/S_{\text{CygA}})_{151.5 \text{ MHz}}\) for all years of measurements using the interferometer RT-14+RT-14(2) at “Staraya Pustyn’” at 151.5 MHz [2, 3].

4 Analysis of the results of long-term measurements of Cassiopeia A flux densities at 927 MHz

Figure 1 shows the measurement results of the Cassiopeia A radio flux density relative to Cygnus A at 927 MHz \((S_{\text{CasA}}/S_{\text{CygA}})_{927 \text{ MHz}} \equiv r_{927}(t)\) made during 25 years (1977–2002) using one and the same 10-m radio telescope at the NIRFI Radio Astronomical Observatory “Staraya Pustyn’”. The straight line of Fig. 1

\[r_{927}(t) = m_{927}(t - \langle t \rangle_{927}) + c_{927},\]

where

\[\langle t \rangle_{927} = 1990.2\] is the mean epoch of measurements at 927 MHz,
\[m_{927} = dr_{927}(t)/dt = -(8.467 \pm 0.390) \cdot 10^{-3}\text{ year}^{-1},\]
\[c_{927} = r_{927}(\langle t \rangle_{927}) = 1.172 \pm 0.003,\]

shows a weighted least-squares fit.

The average value of the secular decrease rate of the Cassiopeia A radio emission over the time interval 1977–2002 is equal to

\[d_{927 \text{ MHz}}(1977–2002) = 100 \cdot m_{927}/c_{927} = -(0.72 \pm 0.03)\% \text{ year}^{-1}.\] (1)

5 Analysis of the results of long-term measurements of Cassiopeia A flux densities at 151.5 MHz

Figure 2 shows the measurement results of the Cassiopeia A radio flux density relative to Cygnus A at 151.5 MHz \((S_{\text{CasA}}/S_{\text{CygA}})_{151.5 \text{ MHz}} \equiv r_{151.5}(t)\). The straight line of Fig. 2
where
\[
\langle t \rangle_{151.5} = 1991.8 \text{ is the mean epoch of measurements at 151.5 MHz},
\]
\[
m_{151.5} = dr_{151.5}(t)/dt = -(8.779 \pm 0.851) \cdot 10^{-3} \text{ year}^{-1},
\]
\[
c_{151.5} = r_{151.5}(\langle t \rangle_{151.5}) = 0.996 \pm 0.008,
\]
shows a weighted least-squares fit. The average value of the secular decrease rate of the Cassiopeia A radio emission over the time interval 1980–2002 is equal to
\[
d_{151.5 \text{ MHz}}(1980−2002) = 100 \cdot m_{151.5}/c_{151.5} = -(0.88 \pm 0.09)\% \text{ year}^{-1}. \tag{2}
\]

![Fig. 2. Flux density of the Cassiopeia A radio emission relative to that of Cygnus A at 151.5 MHz according to the measurements at “Staraya Pustyn” versus time.](image1)

![Fig. 3. Flux density of the Cassiopeia A radio emission relative to that of Cygnus A at 151.5 MHz according to the measurements at “Staraya Pustyn” and the data of [4–6] versus time.](image2)

The measurement results of \((S_{CasA}/S_{CygA})\) of other authors at 151 and 152 MHz are available in the literature for the interval 1966–1993 [4–6]. Fig. 3 shows the results of all known measurements at \(\approx 151.5 \text{ MHz (17 epochs altogether) including “Staraya Pustyn” data together with a straight line of a weighted least-squares fit. The average value of the secular decrease rate of the Cassiopeia A radio emission over the time interval 1966–2002 is equal to}
\[
d_{151.5 \text{ MHz}}(1966−2002) = -(0.81 \pm 0.04)\% \text{ year}^{-1}, \tag{3}
\]
that coincides within the limits of errors with the value (2) obtained at the observatory “Staraya Pustyn” over the interval 1980–2002.

## 6 Discussion

We can see from Fig. 1 that the decline of Cassiopeia A flux density with time is not uniform. For example, in the beginning of the 1980’s, the decrease
was more rapid than at the end of this decade. In addition, in 1979–1980 Cassiopeia A flux density even increased.

It is interesting to compare the obtained values of the secular decrease rate of Cassiopeia A radio emission at 151.5 MHz (2) and 927 MHz (1) with the values of $d$ followed from the empirical formula given in [7]

$$d_\nu(\text{% year}^{-1}) = -(0.97 \pm 0.04) + (0.30 \pm 0.04)\log_{10}(\nu/1000 \text{ MHz})$$

(4)

![Fig. 4. Comparison of the values of the Cassiopeia A secular decrease rate according to formula (4) from [7] (solid curve gives the values of $d$ without account of errors, the dash ones do that with the account of errors) and the values (1) and (2) at 927 and 151.5 MHz, respectively.](image)

Figure 4 shows $d(\nu)$ according to formula (4) (with an account of the errors the values of $d$ according to formula (4) from [7] lie between dash lines in Fig. 4) and the values of $d$ (1) and (2) according to our measurements. As seen from Fig. 4 the values of $d$ obtained mainly by the measurements in the last quarter of the 20-th century are substantially less by the absolute value than the values of $d$ obtained by the measurements in the third quarter of the 20-th century. This testifies to the slowing down with time the decrease of Cassiopeia A radio emission (see also [8]). At the same time the values of the secular decrease rate at 151.5 MHz (2) and 927 MHz (1) do not contradict to the conclusion on the secular flattening of the Cassiopeia A radio spectrum made in [7, 9, 10].

7 Conclusion

As a result of long-term (1977–2002) measurements of the radio flux density of Cassiopeia A relative to Cygnus A at 927 and 151.5 MHz using a single radio telescope (radio interferometer) at a given frequency, we have found the following mean secular decrease rates of the radio flux of Cassiopeia A:

$$d_{927 \text{ MHz}}(1977–2002) = -(0.72 \pm 0.03)\% \text{ year}^{-1},$$

$$d_{151.5 \text{ MHz}}(1980–2002) = -(0.88 \pm 0.09)\% \text{ year}^{-1}. $$
Our values of $d$ obtained by the measurements during the last 25 years are substantially less by the absolute value than the values

$$d(151.5 \text{ MHz}) = -(1.22 \pm 0.05)\% \text{ year}^{-1}$$

and

$$d(927 \text{ MHz}) = -(0.98 \pm 0.04)\% \text{ year}^{-1}$$

which follow from the formula (4) [7]. This indicates to the slowdown of Cassiopeia A radio emission secular decrease.

In addition to this large scale time variation of Cassiopeia A flux density the observations have also shown a small scale (a few years) time variations over the smooth secular decrease.

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**References**

1. Vinyajkin E. N., Razin V. A.: Australian Journal of Physics 32, 93 (1979)
2. Vinyajkin E. N.: Astronomical and Astrophysical Transactions 11, 325 (1996)
3. Vinyajkin E. N.: Astrophys. and Space Sci. 252, 249 (1997)
4. Parker E. A.: Mon. Not. R. Astr. Soc. 138, 407 (1968)
5. Read P. L.: Mon. Not. R. Astr. Soc. 178, 259 (1977)
6. Agafonov M. I.: Astron. Astrophys. 306, 578 (1996)
7. Baars J. W. M., Genzel R., Pauliny-Toth I. I. K., Witzel A.: Astron. Astrophys. 61, 99 (1977)
8. Reichart D. E., Stephens A. W.: Astrophys. J. 537, 904 (2000)
9. Dent W. A., Aller H. D., Olsen E. T.: Astrophys. J. 188, L11 (1974)
10. Vinyajkin E. N., Razin V. A., Khrulev V. V.: Soviet Astronomy Letters 6, 324 (1980)