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Self–calibration in the deep multifrequency surveys

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Abstract. The possibility of using bright radio sources as reference objects in the deep multifrequency surveys of the sky with immovable antenna is discussed. The method is investigated by the data of the sky surveys obtained with the RATAN-600 in the period from 1987 to 2001. The bright sources from the NVSS catalog appearing in the field of view of the telescope were used as reference ones. The mean differences between observed and calculated right ascension ("o–c") and the normalized antenna temperatures were plotted versus observation dates for every set of observations using all reference objects. It turned out that: 1) the mean root square errors (rms) are practically always less than the variations of the value "o–c" from day to day; 2) the value "o–c" could not be neglected at shorter wavelengths, as this steepens the radio spectra of the sources; 3) the mean rms value of the normalized antenna temperature is about 2–5% but variation of the latter from day to day reaches > 10%, this must be taken into account when analyzing the variability of radio sources; 4) this method may be extended to the confusion limited surveys.

Key words: methods: observational – radio surveys

Separation of the systematics in real observational data is one of the most difficult problems in the data reduction process. In many cases this type of errors dominates over all other sources of errors (Lange 2001). Here we discuss this problem in connection with the reduction of data accumulated during deep sky surveys with RATAN-600 radiotelescope.

One of the advantages of the RATAN-600 is a possibility of recording of radio emission of celestial objects in the transit mode at several wavelengths simultaneously. This RATAN-600 peculiarity is practically used for all observational programs including deep surveys of the sky (Khaikin et al. 1972; Parijskij, Shivris 1972; Esepkina et al. 1973). Such first survey of a strip of sky was carried out during the experiment **"Cold"** in 1980–1981 (Parijskij and Korol'kov 1986; Berlin et al. 1981; Parijskij et al. 1991a,b; Berlin et al. 1984).

Accumulation of the sky survey data obtained in many sets of observations in 1980–2001 at 6–7 wavelengths requires development of the methods of combined reduction of these heterogeneous database. For such period of time there were appreciable changes of the receiving equipment: sensitivity of the receivers is improved at short wavelengths; position of the primary feeds on the carriage of the secondary mirror (parabolic cylinder) is changed due to appearance of new receivers; calibrations are changed too. So it is necessary that all scans must be tied (calibrated) to each other both on coordinates and antenna temperature.

Appearance of new generation of large catalogs of radio sources (the NVSS (1.4 GHz) and FIRST (1.4 HGz) catalogs) permits to realize calibration of observed data without transposition of the elements of antenna using only the knownn objects which appeared in the field of view of the radio telescope. We present the results of such an approach here. There are many NVSS objects in the field of view of the RATAN-600 during the sky surveys at 7.6 cm, part of them (sufficiently bright) are suitable as reference objects for calibration of the daily observational data. It must be noted that the spatial resolution of the VLA at 21 cm (the NVSS catalog) practically coincided with that of the RATAN-600 at 7.6 cm ($\sim 60''$). Realizing our approach, we hope not only to improve the determination accuracy of mean parameters of investigated objects at 7.6 cm but to make real the procedure of averaging of the scans at shorter wavelengths, which is "blind" for now because of the overwhelming number of sources are faint.

Now we consider the reasons causing a shift of the radio source position on right ascension (R.A.) from the expected one on the scan.

1. The first and main reason is inaccuracy of positioning of the imaginary focus of the secondary mirror (parabolic cylinder). If the transposition of the secondary mirror takes place every day (sometimes

several times a day), then R.A. coordinate of object may change from day to day on the scans.

2. Time errors of local sidereal time clocks. Skips of impulses or additional ones bring to irregular time marks and lead to a variation of the observed R.A. coordinate.

3. New adjustment of antenna results in a variation of the observed R.A. coordinate from set to set too.

4. Simultaneous failures of a large group of elements of the main mirror of the RATAN-600 result not only in decreasing the antenna efficiency but sometimes in a shift of the observed R.A. coordinate too. However, failures of setting of the individual elements of the antenna do not influence the observed coordinate.

5. Position of radio source relative to the antenna beam axis on the vertical. Transverse offset of the primary feed from the antenna focus leads to the additional shift of source R.A. coordinate because of the aberration for the sources situated higher or lower than the axis of the antenna beam (Esepkina et al. 1980; Parijskij et al. 1989).

Now we consider the main causes of change of antenna temperature of radio sources.

1. Signal–to–noise problem.

2. Variability of radio emission of objects.

3. Accuracy of calibration.

4. Adjustment of the main mirror including adjustment in elevation (there exists a systematic error in inclination of elements of the main mirror).

5. Wrong setting of a sufficiently large number of elements of the main mirror.

6. Wrong offset of the primary feed along the focal axis of the secondary mirror (parabolic cylinder).

7. Change of the atmospheric absorption. It should be noted that the level of the external noise affects both the R.A. coordinate shift and the antenna temperature of radio sources.

Algorithm and programs of current reduction of the observational database were worked out by N.N. Bursov using such regular programs of reduction as *fgr*, *efrat* and others (Verkhodanov 1997).

Separation of objects on the scans, using Gauss analysis, at 7.6 cm (the most sensitive receiver), recalculation of the observed R.A. coordinates to the epoch 2000.0 and comparison them with expected NVSS ones permits obtaining the difference between the observed and the calculated coordinates of objects ("o–c"). Antenna temperature corrections are possible as well. Averaging of the "o–c" value on the given day over all sources and deriving the day-to-day "o–c" dependence for the given set of observation resolves, in principal, the problem of averaging of all sets of observations.

Error of determination of coordinates on the scans is estimated as

$$\Delta\varphi \sim 1.4(\Delta T_a/T_a) \times \varphi,$$

where $T_a/\Delta T_a$ is the signal–to–noise ratio, φ is the half-width of the antenna beam of the radio telescope. If the antenna temperature $T_a \geq 100$mK, then the position of observed sources is independent of the signal–to–noise ratio. As the signal–to–noise ratio is sufficiently worse at shorter wavelengths and the flux density of objects is smaller (exept for sources with flat spectra), so the obtained calibration at 7.6 cm must be taken into account at shorter wavelengths where their significance increases because of smaller beam.

In studying the variability of objects the relative variations of the antenna temperature from day to day over all bright sources of the set must be taken into account.

We present here the calibration curves of variation of the "o–c" and $T_a/T_{a(mean)}$ values for all sets of the experiment "Cold" at 7.6 cm. It should be noted that the antenna was installed at the declination of the object SS 433 ($\delta \approx 5°$) for all sets. For those sets of observations for which the primary feed at 7.6 cm was installed at the focus of the radio telescope (without the primary feed transverse offset, along the carriage of the secondary mirror) "o–c" dependence on the object declination is absent. Such sets were carried out in 1987–88 and in 1990 (2 sets in July and December) and in October of 1991.

In April 2001 observations were carried out using the periscopic system of the RATAN-600 (the southern sector of the antenna with the flat reflector). In such observations there should be no dependence of "o–c" on the declination of the radio source either (in this case the antenna pattern is a "knife" type).

Now we consider our sets of observations in detail.

1st set:

16.12.1987 – 12.01.1988 ("Cold VII")

Observations were carried out using the northern sector of the RATAN-600. Transpositions of the antenna and secondary mirror were made directly before 19^h of local sidereal time. Dependence of the mean difference between the observed and the calculated R.A. coordinates "o–c" in sec on the observation date and also the mean square errors (rms) over all sources are given in Fig.1.

One-second jump of "o–c" on 4.01.1988 is connected with IAU regulation of time by World Time Service. Mean rms value is 0.063 sec. Mean curve $T_a/T_{a(mean)}$ over all objects with rms errors (mean rms value =2.3%) as a function of the observation date is presented in Fig.2.

All curves were obtained with regard to transition of the observation date at 6^h of local sidereal time from 25.12 to 26.12.1987 and at 7^h from 9.01 to 10.01.1988.

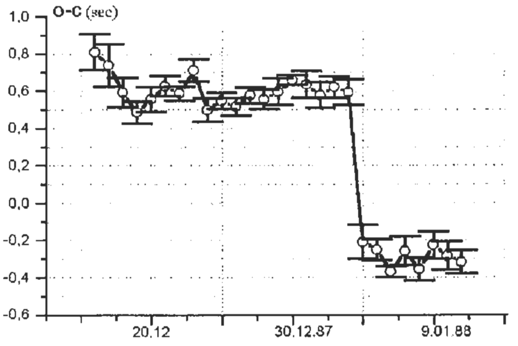

Figure 1: *"Cold VII". "o-c" value as a function of observation date. The following objects were used: 0343+05 (260mK), 0350+05 (42mK), 0426+05 (32mK), 0427+05 (142mK), 0505+05 (229mK), 0624+05 (48mK), 0733+05 (134mK), 0820+05 (46mK), 1015+05 (32mK), 1045+05 (33mK), 1124+05 (88mK), 1131+05 (53mK), 1145+05 (120mK), 1148+05 (46mK), 1342+05 (51mK), 1911+05 (141mK), 2117+05 (66mK), 2130+05 (622mK), 2245+05 (110mK), 2151+05 (39mK).*

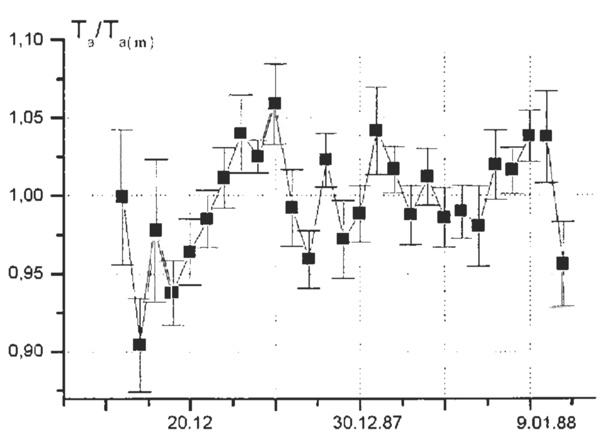

Figure 2: *"Cold VII". Normalized antenna temperature as a function of observation date. The same sources (exept 1911+05) as in Fig. 1 were averaged.*

2nd set:
2.07 – 31.07.1990 ("Cold X")

Conditions of the observations are the same as in the previous set. Transposition of the antenna and the secondary mirror were made before 12^h of local sidereal time (there exist only 1 scan in 9^h interval and 2 scans in 10^h and 11^h intervals). The mean curve "o–c" values in the local sidereal time interval $15^h - 22^h$ (mean rms value =0.18 sec) for different observation dates are presented by the solid line in Fig. 3a and in the intervals $15^h - 17^h$ and $19^h - 22^h$ — by the dotted line. Large errors are due to the limited number of sources. For other intervals the number of objects is too small (only on 2 scans).

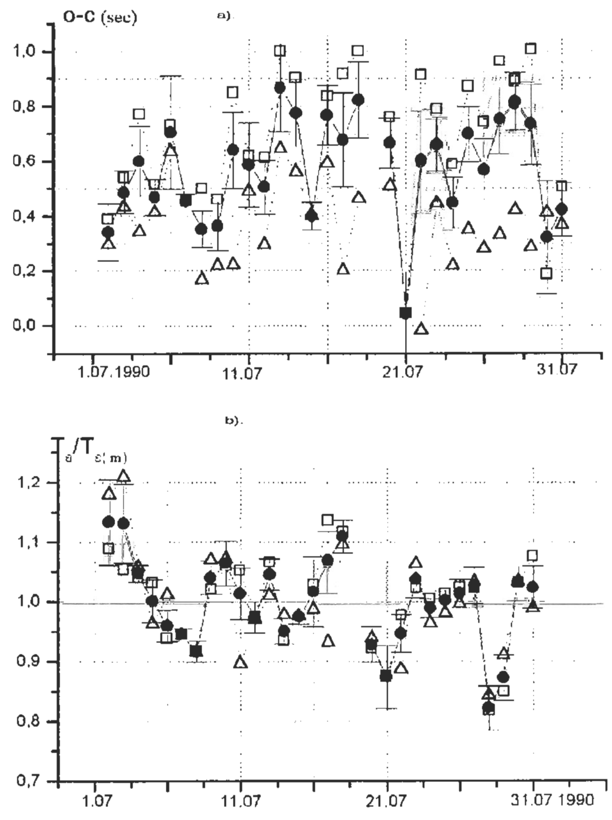

Figure 3: *"Cold X". a) "o–c" dependence for different intervals of local sidereal time: $15^h - 22^h$ (solid circles), $15^h - 17^h$ (squares), $19^h - 22^h$ (triangles). b) Normalized antenna temperature dependence on the observation date for different intervals of local sidereal time (designations are the same). Following sources were used: 1524+05 (34mK), 1543+05 (46mK), 1616+05 (129mK), 1651+05 (1945mK), 1651a+05 (935mK), 1754+05 (122mK), 1755+05 (43mK), 2117+05 (58mK), 2130+05 (553mK), 2245+05 (156mK).*

$T_a/T_{a(mean)}$ ratio as a function of the observation date for the local sidereal time interval $15^h - 22^h$ is given by the solid line in Fig. 3b, for the intervals $15^h - 17^h$ and $19^h - 22^h$ – by the dotted line. The mean rms value is 3%.

3rd set:
12.12 – 31.12.1990 ("Cold XI")

Conditions of observations are the same as in the previous sets. There were no observations in the local sidereal time intervals $1^h - 2^h, 4^h - 7^h, 17^h - 20^h$; they began in the intervals $21^h - 24^h$; the observations in the $8^h - 9^h$ interval began from 21.12 only and in the interval $10^h - 11^h$ from 26.12. Apparently, transpositions of the antenna and the secondary mirror were made 3 times a day.

Two mean curves of "o–c" values for the local side-

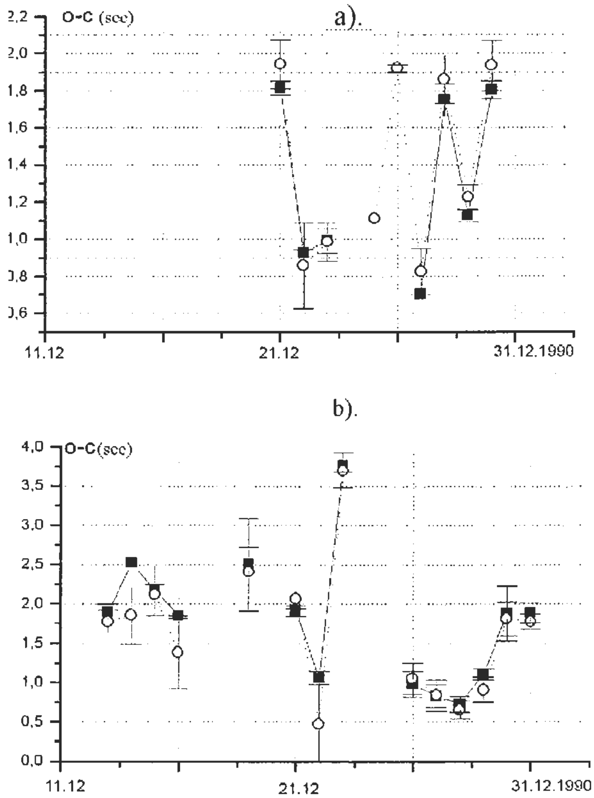

Figure 4: *"Cold XI". "o–c" values against observational dates for different intervals of local sidereal time: a)* $21^h - 22^h$ *(solid squares),* $21^h - 24^h$ *(circles); b)* $10^h - 16^h$ *(solid squares),* $8^h - 16^h$ *(circles). The following sources were used: 2117+05, 2130+05, 2245+05, 0820+05, 1045+05, 1124+05, 1131+05, 1145+05, 1148+05, 1342+05, 1524+05, 1651+05, 1651a+05.*

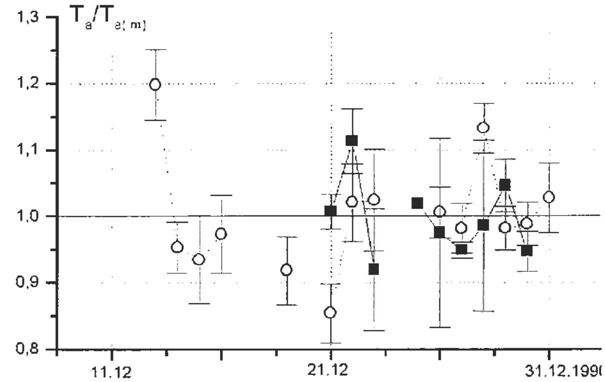

Figure 5: *"Cold XI".* $T_a/T_{a(mean)}$ *ratio as a function of the observation date for different intervals of local sidereal time:* $21^h - 24^h$ *(solid square),* $8^h - 16^h$ *(circles). The same as in Fig. 4 sources were used.*

real time intervals $21^h - 22^h$ (the mean rms value is 0.048 sec) and for $21^h - 24^h$ (the mean rms value is 0.11 sec) are shown in Fig. 4a, and the curves for the intervals $10^h - 16^h$ (the mean rms value is 0.23 sec) and $8^h - 16^h$ (the mean rms value is 0.19 sec) are presented in Fig. 4b, respectively.

The values of normalized mean antenna temperature depending on the observation date in the local sidereal time interval $21^h - 24^h$ (the mean rms value is 5%) and in $8^h - 16^h$ (the mean rms is 4.8%) are given in Fig. 5.

4th set:

29.09 – 29.10.1991 ("Cold XII")

Observations were carried out with the help of the northern sector of the RATAN-600. Transposition of the antenna and the secondary mirror were made before 19^h of the local sidereal time; observations in the interval $15^h - 16^h$ were not carried out and there is only one scan at $17^h - 18^h$ 29.10. Fig. 6a shows variation from day to day of "o–c" values in sec with errors for objects in all local sidereal time intervals (solid line) and in intervals $19^h - 22^h$, $3^h - 11^h$ (dotted line). The mean rms error is 0.05 sec, which is essentially less than variation from day to day of "o–c" mean value (0.25 sec). The normalized antenna temperature as a function of observation date is given in Fig. 6b (the mean rms error = 2.2%).

All obtained curves were constructed taken into account a transition of date at 0^h of local sidereal time from 25 to 26.09.1991. Variation of T_a more than 10% is noticed only on 10.10 and 21.10.1991.

5th set:

7.04 – 7.05.2001 ("Cold 01.4")

Observations were carried out using the southern sector with the flat reflector. The primary feed was shifted from the focus along the focal line of parabolic cylinder to 19.6 sec (3.35 λ). As observations are absent in the local sidereal time intervals $23^h - 3^h$, transposition of the flat reflector and perhaps of the secondary mirror was before 3^h. The mean curve "o–c" as a function of the observation date is shown in Fig. 7a. There is one jump of "o–c" value on 20.04.2001 connected with only one source. The mean rms error is 0.1 sec. Mean curve ($T_a/T_{a(mean)}$) over all bright objects is given in Fig.7b. The mean rms error = 3.8%. Both curves were constructed taking into account the transition of the observation date at 13^h of the local sidereal time from 25.04 to 26.04; at 12^h from 9.04 to 10.04.2001.

Now we consider the sets of observations where the primary feed offset from the focus of radio telescope along the axis of parabolic cylinder at 7.6 cm was 15.8 sec (2.7 λ). These observations were carried out from September 1997 through 2000.

6th set:

5.09 – 8.09.1997 ("Cold 97.9").

Observations were carried out with the help of

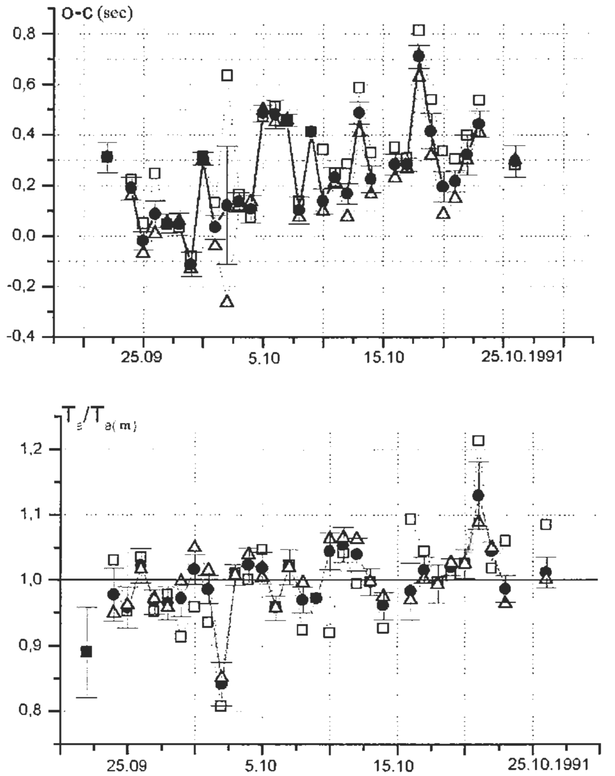

Figure 6: *"Cold XII". a) "o–c" value — observation date dependence for different intervals of local sidereal time: for all interval (circles) and for $19^h - 22^h$ (squares), $3^h - 11^h$ (triangles). b) Normalized antenna temperature dependence on the observation date for different intervals of local sidereal time (designations are the same). The following sources were used: 0343+05, 0427+05, 0505+05, 0624+05, 0733+05 (63mK), 0820+05, 1045+05, 1124+05, 1131+05, 1145+05, 1146+05 (38mK), 1148+05, 2117+05, 2130+05, 2245+05.*

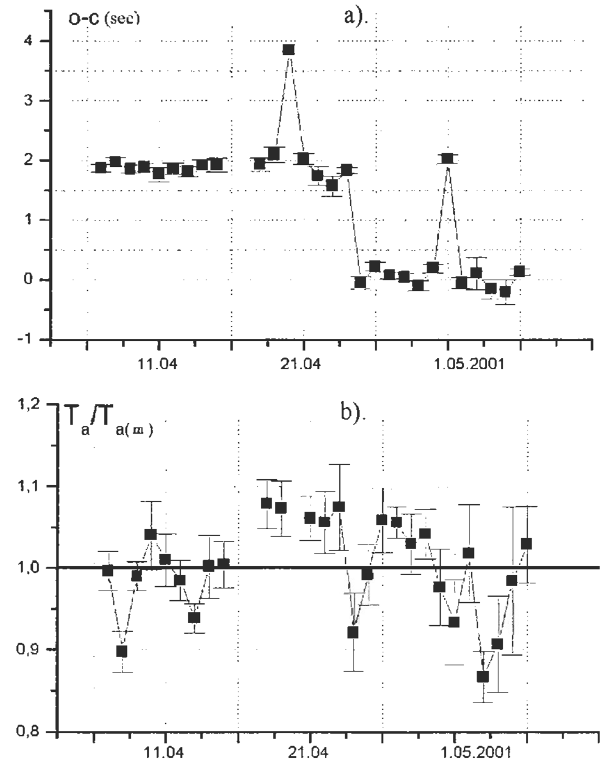

Figure 7: *"Cold 01.4". a) "o–c" values against observational dates. b) Normalized antenna temperature dependence on the observation date. The following sources were used: 0343+05, 0350+05, 0426+05, 0427+05, 0505+05, 0534+05, 0619+05 (58mK), 0630+05, 0733+05 (63mK), 0742+05 (49mK), 1038+05 (115mK), 1124+05, 1131+05, 1342+05, 1543+05, 1616+05, 1651+05, 1938+05 (70mK), 2117+05, 2123+05, 2130+05, 2245+05.*

the northern part of the RATAN-600. Results of this set are not presented because of the small number of observations.

7th set:
1.05 – 11.05.1999 ("Cold 99.5")

Observations were carried out using the northern part of the RATAN-600. In the local sidereal time intervals $0^h - 7^h$ observations are absent. Transpositions of the antenna and the secondary mirror were made before 7^h and, possibly, before 20^h of the local sidereal time. Two mean curves of "o–c" as a function of observation date for different ΔH are shown in Fig. 8a. The mean rms error for the first curve is 0.21 sec, for the second one it is 0.26 sec.

The large errors are connected with a small number of bright objects over which the procedure of averaging was made. $T_a/T_{a(mean)}$ dependence as a function of observation date for all bright sources is presented in Fig. 8b. The mean rms error is 5.5%.

8th set:
6.11 – 22.11.1999 ("Cold 99.B")

Observations were carried out with the aid of the northern part of the RATAN-600. In the local sidereal time intervals of $0^h - 2^h, 5^h - 6^h$, $12^h - 13^h$ observations were absent. Transpositions of the antenna and the parabolic cylinder were made during this period of time. So the procedure of averaging of "o–c" values over all bright objects may be done only in the local sidereal time intervals between transpositions of the antenna. Four mean curves of "o–c" values depending on the observation date for different intervals of the local sidereal time are shown in Fig.9a. There is a jump of "o–c" value of about 2 sec on all these curves on 6.11, most likely it is connected with time error of local sidereal time clocks. Mean values of "o–c" and mean rms errors are given in Table 1 (values of 6.11.1999 are not included in the procedure of averaging).

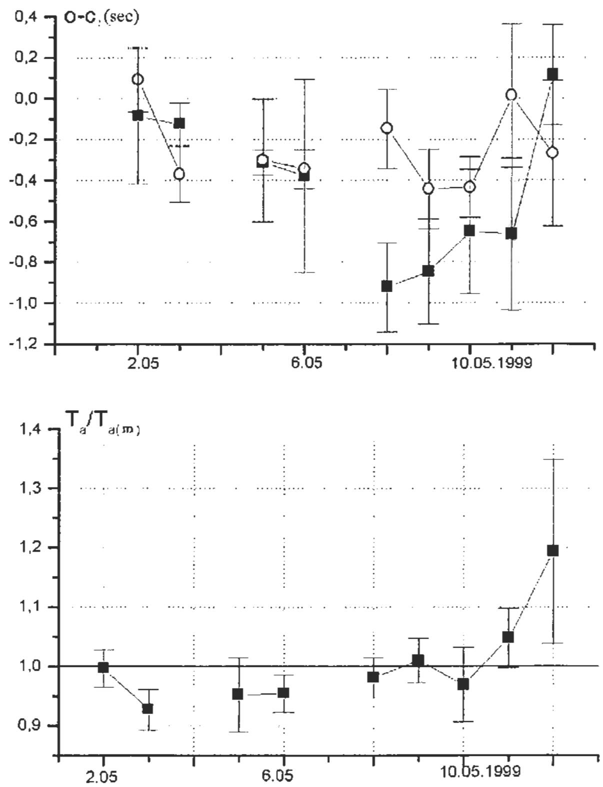

Figure 8: *"Cold 99.5". a) "o-c" values against observation date for the sources with* $|\Delta H| < 2'.5$ *(circles) and* $2'.5 < |\Delta H| < 4'$ *(squares). b)* $T_a/T_{a(mean)}$ *dependence on the observation date. The following sources were used: 1045+05, 1124+05, 1131+05, 1145+05, 1146+05 (44mK), 1148+05, 1150+05 (48mK), 1342+05, 1524+05, 1616+05, 1651+05, 1754+05, 2117+05, 2130+05, 2245+05.*

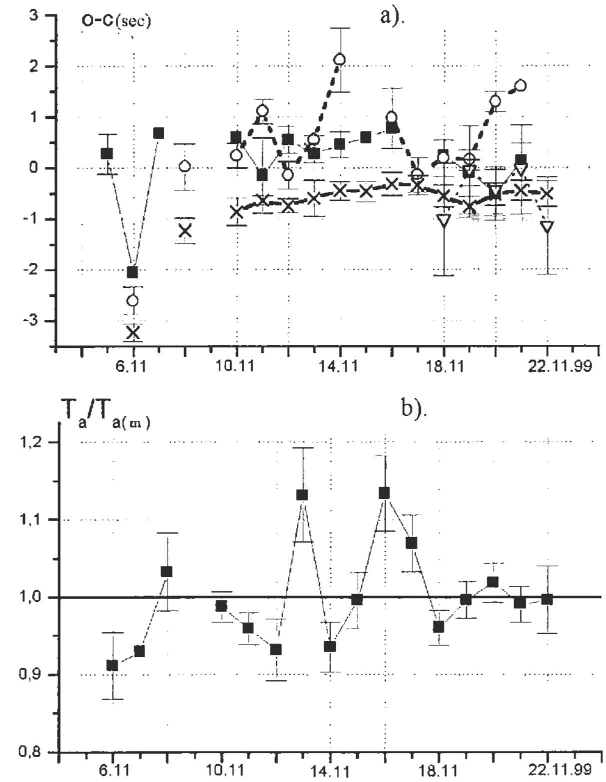

Figure 9: *"Cold 99.B". a) "o-c" value dependence for different intervals of local sidereal time:* $22^h - 23^h$ *(squares),* $15^h - 16^h$ *(circles, there were observations only from 18.11.1999);* $7^h - 11^h$ *(skating crosses) and* $3^h - 4^h$ *(triangles). b) Normalized antenna temperature dependence on the observation date. The following sources were used: 0343+05, 0350+05, 0426+05, 0427+05, 0733+05, 0742+05 (31mK), 1124+05, 1131+05, 1145+05, 1146+05, 1148+05, 1150+05, 1543+05, 1559+05 (32mK), 1616+05, 2245+05, 2251+05 (29mK), 2320+05 (53mK).*

Table 1: *"Cold 99.B". The mean "o–c" values and rms for diffefent intervals of local sidereal time*

Local sidereal time interval	"o–c"	rms
h	sec	sec
3–4	−0.537	0.85
7–11	−0.601	0.215
15–16	0.662	0.327
22–23	0.289	0.364

$T_a/T_{a(mean)}$ values as a function of observation date are shown in Fig. 9b. As the affect of the transposition of the antenna and secondary mirror on $T_a/T_{a(mean)}$ values is usually negligible, the procedure of averaging was made over all intervals of the local sidereal time. Mean rms error is 3.5%.

9th set:
30.04 – 5.05 2000 ("Cold 00.5")

Results of this set are not presented because of the small number of observations.

10th set:
15.07 – 2.08 2000 ("Cold 00.8")

Observations were carried out using the northern part of the RATAN-600. There are only records on 29 and 30.07 in the interval of the local sidereal time $3^h - 12^h$. Transposition of the antenna and the parabolic cylinder were made before 14^h of the local sidereal time. As the observations were carried out with the transverse feed offset from the focus of the radio telescope by 2.7λ, there must be "o–c" value dependence on difference of source position from the radio telescope electrical axis over the elevation (ΔH). "o–c" values as a function of observation date in the local sidereal time interval $15^h - 17^h$ with different

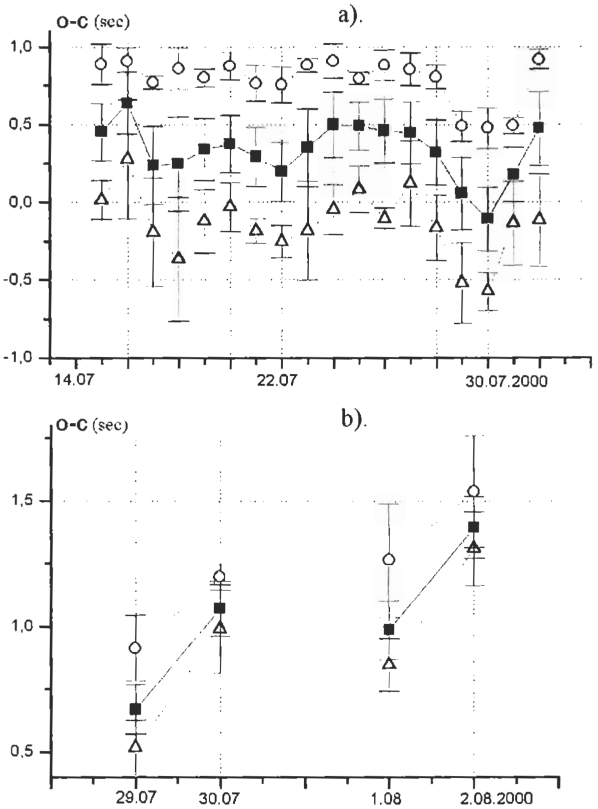

Figure 10: *"Cold 00.8". a) "o–c" values against the observation date with different ΔH: $|\Delta H| < 1'$ (circles) — the mean rms error is 0.088 sec, with $|\Delta H| < 2'.5$ (triangles) — the mean rms error is 0.218 sec, and mean "o–c" curve over all objects independent on ΔH is designated with squares. b) Objects with $|\Delta H| < 2'$ are marked with circles, with $|\Delta H| > 2'$ — with triangles and sources with arbitrary ΔH — squares. The following sources were used: 0426+05, 0427+05, 0505+05, 0534+05, 0624+05, 0733+05, 1045+05, 1124+05, 1131+05, 1145+05, 1146+05, 1148+05, 1150+05, 1257+05 (38mK), 1543+05, 1559+05, 1616+05, 1651+05, 1651a+05, 1703+05 (33mK), 1706+05, 1754+05, 1755+05 (43mK).*

ΔH values are given in Fig. 10a. Fig. 10b demonstrates analogous relations in the interval 4^h – 12^h. Fig. 11 shows the ratio $T_a/T_{a(mean)}$ as a function of observation date for different intervals of the local sidereal time.

Now we consider the sets of observations where the primary feed offset along the focal axis of the parabolic cylinder is 12.1–12.8 sec (2.1–2.2 λ).

11th–12th sets:

9.01 – 16.01; 1.02 – 1.03 1991

("Cold '91")

Observations were carried out using the northern part of the RATAN-600. Transposition of the an-

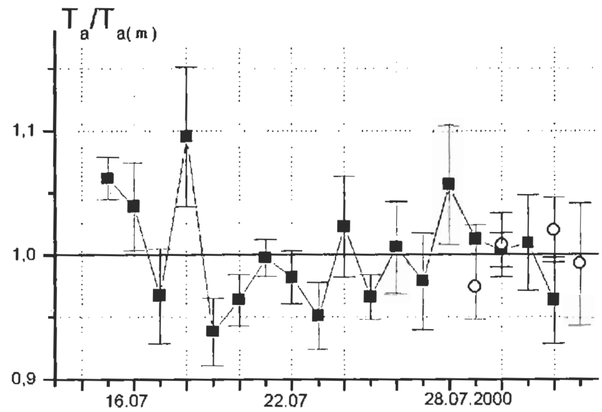

Figure 11: *"Cold 00.8". $T_a/T_{a(mean)}$ dependence on observation date for following intervals of local sidereal time: for 15^h – 17^h (squares, mean rms error is 3%) and for 4^h – 12^h (circles, mean rms error is 3.1%). The same as in Fig. 10 sources were used.*

tenna and the parabolic cylinder were made before 22^h of the local sidereal time. Observations in 11th set were made from 23^h to 15^h and in the 12th set — from 1^h to 15^h of the local sidereal time. "o–c" dependence on observation date for the 11th set for the objects with $|\Delta H| \leq 2'$ for various intervals of time are given in Fig. 12a. A jump of "o–c" value on 12.01.1991 (3.51±0.3 sec) is connected with time error of the local sidereal time clocks and it exists only in the interval 1^h – 8^h. Apparently, jump of "o–c" value on 13.01.1991 is also connected with time error of the clocks of the local sidereal time, but it is observed throughout the interval 1^h – 15^h. Fig. 12b demonstrates the mean curve of "o–c" values over all intervals of the local sidereal time, mean rms error is 0.129 sec. Fig. 13a,b shows the similar curves for the 12th set of observation (designations are the same). "o–c" value is omitted on 1.02.1991, it is 11.73 sec. Figure 14 presents dependence of normalized temperature on observation date for the both sets, mean rms error = 4%.

All curves were constructed with regard of changing of dates on 10.01 at 7^h, on 8.02 — at 9^h and on 24.02 — at 10^h.

13th set:

1.04 – 10.04; 21.04 – 11.05 1994

("Cold XIV")

Observations were carried out with the northern part of the RATAN-600. Perhaps transpositions of antenna were made before 3^h of the local sidereal time but the possibility that they were absent is not excepted at all. However the antenna was installed at other elevation between these subsets so it is trivial that transposition of antenna was made. Fig. 15 demonstrates "o–c" values as a function of ΔH for 2 subsets. It is well known that if aberration is present,

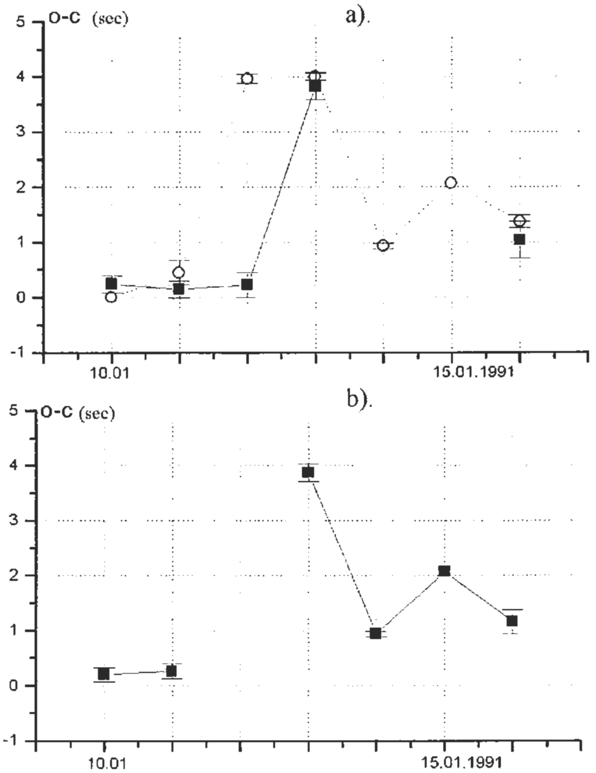

Figure 12: *11th set: "Cold '91". a) "o–c" values as a function of observation date with different* $|\Delta H| \leq 2'$ *in interval* $3^h - 8^h$ *(dotted line, circles), the mean rms error is 0.137 sec and in interval* $10^h - 11^h$ *(square), the mean rms error is 0.197%. b) mean "o–c" values over all intervals. The following sources were used: 0343+05, 0350+05, 0427+05, 0505+05, 0624+05, 0733+05, 1045+05, 1124+05, 1131+05, 1145+05, 1148+05.*

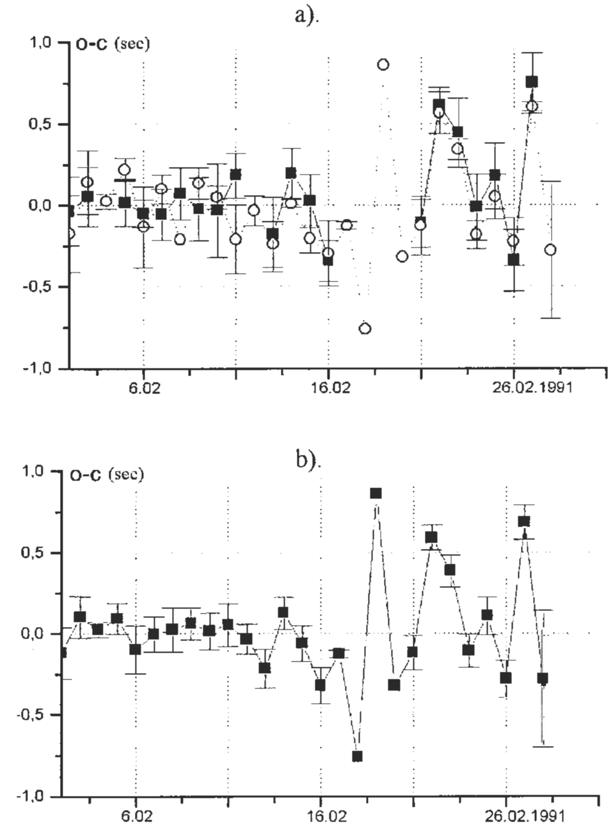

Figure 13: *12th set: "Cold '91". a) "o–c" value as a function of the observation date with* $|\Delta H| \leq 2'$. *b) mean "o–c" values over all intervals (designations as in Fig. 12). The following sources were used: 0343+05, 0350+05, 0427+05, 0505+05, 0624+05, 0733+05, 1045+05, 1124+05, 1131+05, 1145+05, 1148+05.*

the off axis scan have additional time lag dependent on the value of ΔH. Fig. 16a shows "o–c" dependence on observation date for the objects with $|\Delta H| \leq 2\rlap{.}'5$. The fact that the mean "o–c" value essentially differs for these intervals attracts attention. The mean "o–c" value is 0.78 sec for the interval $15^h - 24^h$ and is 0.52 sec for $3^h - 11^h$. Perhaps, it is explained partially by a different mean value of $|\Delta H|$: for the sources used for averaging in the first interval $|\Delta H| = 4\rlap{.}'2$ and for the second interval — $|\Delta H| = 1\rlap{.}'3$. But at least the possibility of transposition of the parabolic cylinder is not be excluded. "o–c" dependence on observation date in the interval $3^h - 24^h$ is presented in Fig. 16b. The mean rms value is 0.068 sec. Fig. 17a,b shows normalized antenna temperature dependence on observation date for different intervals of the local sidereal time.

It should be noted that the source 1911+0458 demonstrates strong variability of flux density in this period of time, mean rms value is increased about 1.7 times if this object was included in the procedure of averaging. So it was excluded. All curves for all intervals of time were obtained taking into account transition of the observation date at 13^h of local sidereal time from 25.04 to 26.04.1994.

14th set:
6.03 – 10.03 1997 ("Cold 97.3")

Observations were carried out using the northern sector of the RATAN-600. Observational cycle was short and the results of this set are not presented.

Now we consider the sets with other positions of the primary feed at $\lambda = 7.6$ cm along the carriage of the secondary mirror.

15th set:
16.09 – 31.10 1993 ("Cold XIII")

Observations were carried out with the northern part of the RATAN-600. The primary feed was shifted from the focus of the radio telescope along the carriage of the parabolic cylinder by 9.1 sec (1.56 λ). Transpositions of the antenna and the secondary mirror were made before 19^h of the local sidereal time. Fig. 18 demonstrates "o–c" as a function of ΔH (de-

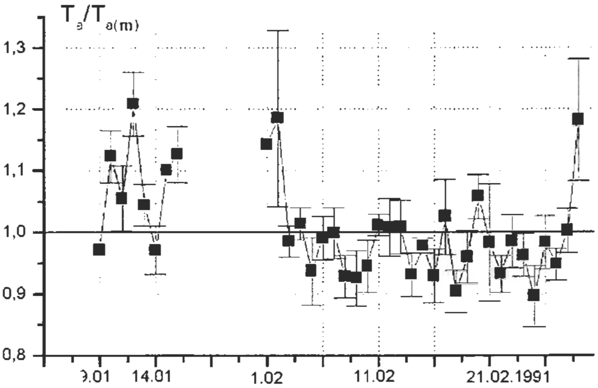

Figure 14: *"Cold '91". $T_a/T_{a(mean)}$ dependence on observation date for the both sets.*

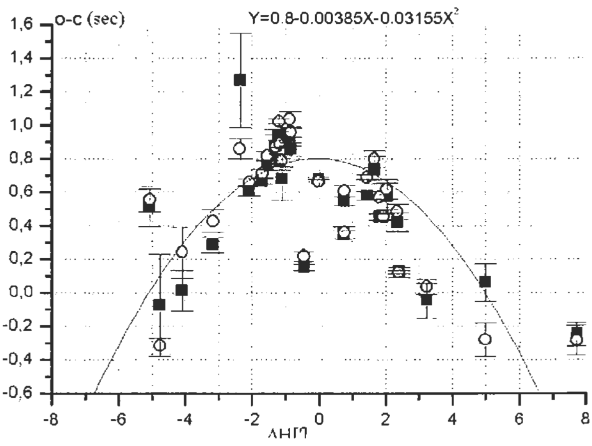

Figure 15: *"Cold XIV". "o–c" values as a function of ΔH for 2 subsets.*

viation in elevation of the source position from the electrical axis of the radio telescope is given in arcmin).

Fig. 19a shows "o–c" dependence on observation date for the objects with $|\Delta H| \leq 2'.5$; mean rms value = 0.067 sec. It should be noted that "o–c " values for 15.10 (observations at 0^h, $2^h, 3^h$ were absent), 16 and 17.10.1993 are not plotted on this curve, they are given in Table 2.

The $T_a/T_{a(mean)}$ dependence on observation date for all bright objects independent of ΔH is presented in Fig. 19b. Mean daily rms value is 2.6%. Both curves were obtained taking into account transition of the observation date at 23^h of the local sidereal time from 24.09 to 25.09, at 1^h — from 9.10 to 10.10 and at 2^h — from 24.10 to 25.10. The sharp change of the normalized temperature after 25.10 is connected with the incorrect value of calibration (the noise track on the daily scans decreased correspondingly after this date). The cause of variation of the antenna temperature from 1.10 to 25.10 is unclear yet (the noise track is the same as up to 1.10).

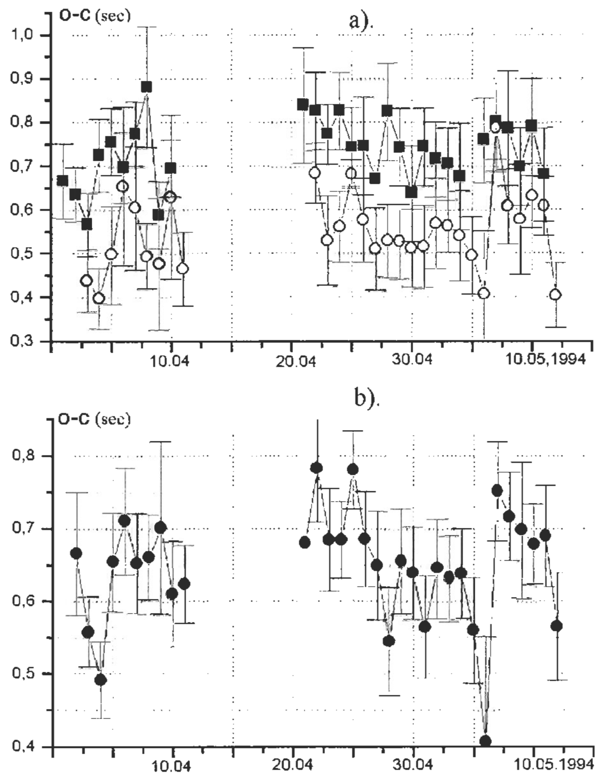

Figure 16: *"Cold XIV". a) "o–c" value as a function of observation date with $|\Delta H| \leq 2'.5$ (squares — for the sources in the local sidereal time interval $3^h - 11^h$, circles — for $15^h - 24^h$ interval). b) "o–c" dependence on observation date in $3^h - 24^h$ interval. The following sources were used: 0343+05, 0426+05, 0427+05, 0505+05, 0534+05, 0624+05, 0733+05, 0820+05, 1045+05, 1124+05, 1131+05, 1145+05, 1148+05, 1150+05, 1524+05, 1543+05, 1616+05, 1706+05, 1754+05, 1755+05, 1911+05,2130+05, 2245+05.*

Superposition of the scans for the source 0343+05 is given in Fig. 20. After taking account of "o–c" and $T_a/T_{a(mean}$ relations the scattering in positions decreased and amplitudes of the individual gaussians equalized considerable: the mean antenna temperature increases by 20%, the dispersion of the scans decreases 3 times (Fig. 21).

Conclusions

1. We have demonstrated that the new self-calibration method can help greatly in removing the systematics in R.A. measurements just using NVSS objects in the daily field of view of the RATAN-600 as "secondary" calibrators. Our systematics reflects the effects in the time intervals, where there were no changes in the antenna position, especially in the position of the secondary mirror.

2. After removing the systematics in R.A. (individual for each set) the positional accuracy about

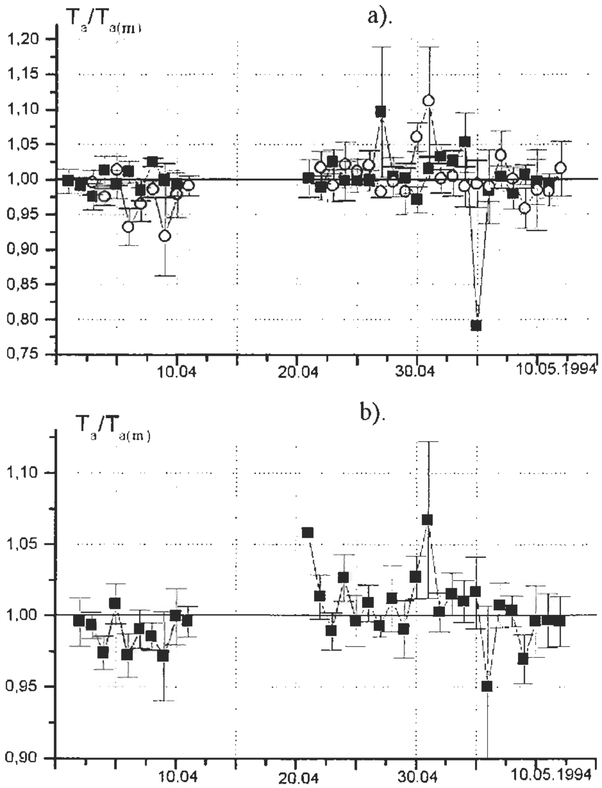

Figure 17: *"Cold XIV". a) $T_a/T_{a(mean)}$ dependence on observation date: objects are marked with squares for $3^h - 11^h$ interval of local sidereal time and with circles — for $3^h - 24^h$. b) $T_a/T_{a(mean)}$ as a function of observation date in $3^h - 24^h$ interval. The mean rms value is 2.4%. The same sources as in Fig. 16, exept 1911+05 were used.*

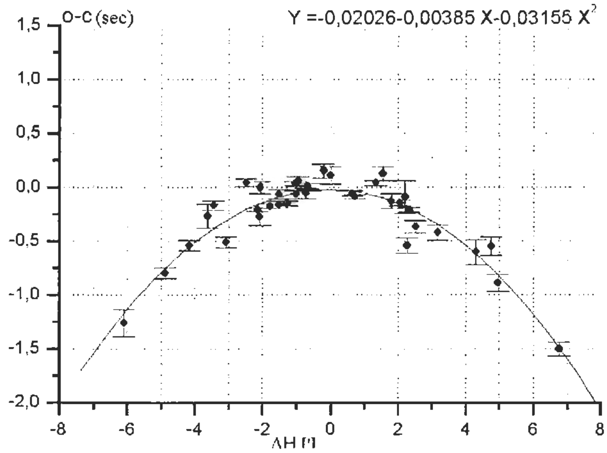

Figure 18: *"Cold XIII". "o–c" values as a function of ΔH.*

Table 2: *"Cold XIII". The mean "o–c" values for diffefent intervals of local sidereal time for 3 days of observation*

Date	Local sidereal time interval	"o–c"
	h	sec
	0	-20.4
15.10.93	3 - 16	-
	17 - 23	-
	0	-20.55
16.10.93	3 - 16	-20.12
	17 - 23	-20.38
	0	-
17.10.93	3 - 16	-20.17
	17 - 23	-

1 arcsec at 7.6 cm wavelenght was achieved for objects stronger than 100 mJy.

3. Variations in the peak flux density inside the set may be supressed by a factor of 3 using this self-calibration method. We may use systematics in positions determined at 7.6 cm in the reduction of the shorter wavelenghts data. If not, we shall have non-correct spectral index for radio sources. At the shortest wavelenght we can have nearly null result of "blind" averaging of all data in the same sky region.

4. We suggest that in the case of "confusion limited" deep surveys of big fields, NVSS "confusion limited" model can be used as a position self-calibrator. Cross-correlation between NVSS sky convolved with two-dimensional antenna beam can reveal the R.A. systematics.

We recommend all users of **"Cold"** surveys database to take into account discovered systematic errors.

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References

Berlin A.B., Bulaenko E.B., Gol'nev V.Ja. et al., 1981, Pis'ma Astron. Zh., **76**, 290

Berlin A.B., Gassanov L.G., Gol'nev V.Ja., Korol'kov D.V., Parijskii Yu.N., 1984, Soobshch. Spets. Astrofiz. Observ., No.41

Berlin A.B., Gassanov L.G., Gol'nev V.Ja., Korol'kov D.V., Parijskii Yu.N., 1984, Soobshch. Spets. Astrofiz. Observ., No.42

Esepkina N.A., Korol'kov D.V., Parijskii Yu.N., 1973, in: "Radiotelescopes and radiometers" (in Russian), "Nauka", 111

Esepkina N.A., Bahvalov N.S., Vasil'ev B.A., Vasil'eva L.G., Vodovatov I.A., Temirova A.V., 1980, Astrofiz. issled. (Izv. SAO), **12**, 106

Khaikin S.E., Kaidanovskii N.L., Parijskii Yu.N., Esepkina N.A., 1972, Izv. Glavnoi Astron. Obs., No.188, 3

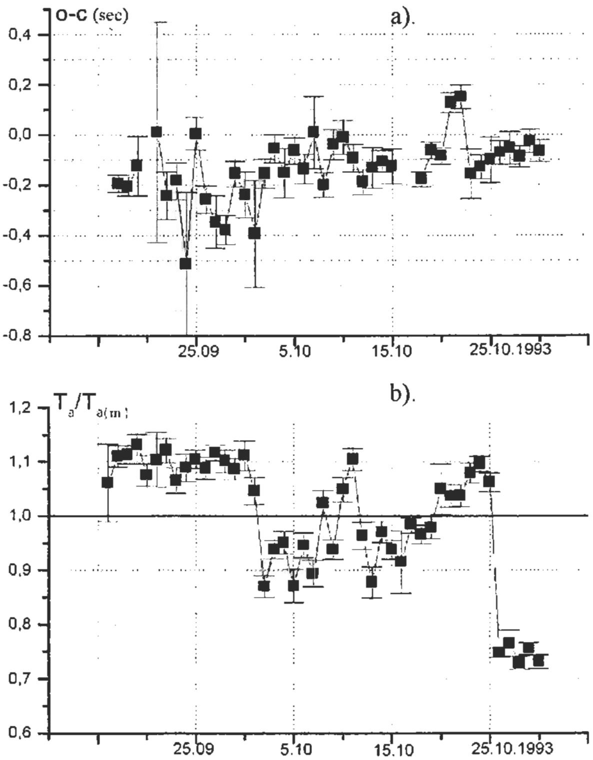

Figure 19: *"Cold XIII". a) "o–c" value as a function of observation date with* $|\Delta H| \leq 2'.5$. *b)* $T_a/T_{a(mean)}$ *dependence on observation date for all bright objects independent on* ΔH. *Following sources were used: 0009+05 (44mK), 0039+05 (44mK), 0343+05, 0350+05, 0426+05, 0427+05, 0505+05, 0534+05, 0619+05 (34mK), 0624+05, 0733+05, 0753+05 (32mK), 0820+05, 0849+05 (32mK), 0949+05 (34mK), 1015+05 (33mK), 1045+05, 1124+05, 1131+05, 1142+05(37mK), 1145+05, 1146+05, 1148+05, 1150+05, 1257+05, 1342+05, 1456+05 (44mK), 1524+05, 1543+05, 1616+05, 1651+05, 1651a+05, 1703+05, 1706+05, 1754+05, 1755+05, 1911+05, 2110+05 (40mK), 2117+05, 2130+05, 2245+05, 2251+05.*

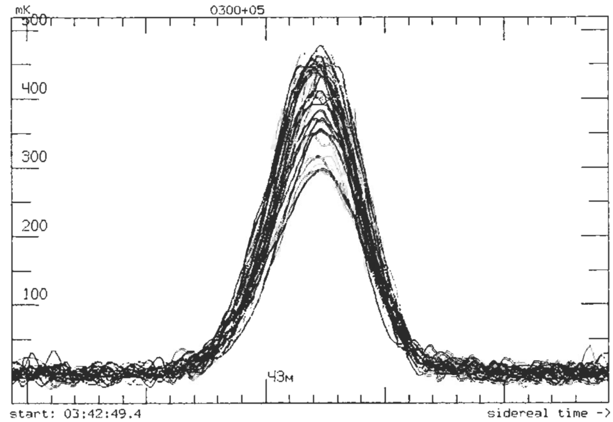

Figure 20: *"Cold XIII". Superposition of the scans for the source 0343+05 without taking into account calibration "o–c" and* $T_a/T_{a(mean)}$ *curves.*

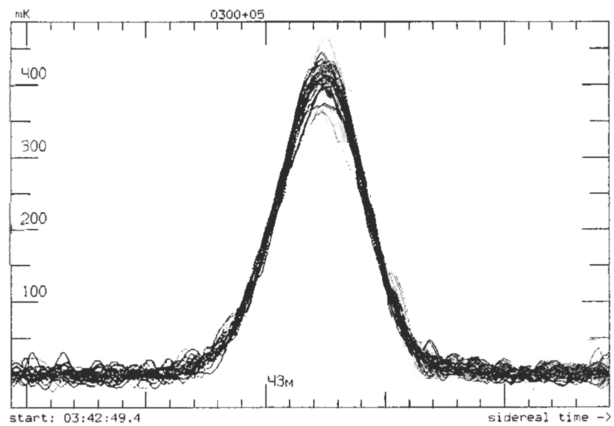

Figure 21: *"Cold XIII". Superposition of the scans for the source 0343+05 taking into account calibration "o–c" and* $T_a/T_{a(mean)}$ *curves.*

Lange A., 2001, in: "The Scientific Programme of Planck", First General Meeting 2001, 183

Parijskii Yu.N., Shivris O.N., 1972, Izv. Glavnoi Astron. Obs., No.188, 13

Parijskij Yu.N., Korol'kov D.V., 1986, Astrophys. and Space Rev., **5**, 1

Parijskij Yu.N., Bursov N.N., Lipovka N.M., Soboleva N.S., Temirova A.V., 1991, Astron. Astrophys. Suppl. Ser., **87**, 1

Parijskij Yu.N., Bursov N.N., Lipovka N.M., Soboleva N.S., Temirova A.V., Chepurnov A.V., 1991, Astron. Astrophys. Suppl. Ser., **96**, 583

Parijskij Yu.N., Bursov N.N., Vilebinskii R., Vitkovskii V.V., Kljain Ul., Lipovka N.M., Soboleva N.S., Temirova A.V., 1989, Astrofiz. issled. (Izv. SAO), **27**, 95

Verkhodanov O.V., 1997, in: "Astron. Continuum Data Analysis Software and Systems VI", eds.: G.Hunt, H. Payne, ASP Conference Series, **125**, 46