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SYSTEMATIC ERRORS IN OBSERVATIONAL DOUBLE STAR CATALOGUES

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SUMMARY: The comparison of the Preliminary Compilation of DS-Programme Star Positions (PCDS) with the catalogues of double stars (Belgrade, Kiev, Kharkov, Odessa, Moscow 1, Moscow 2, Kazan) was made in right ascension, declination, magnitude and spectral type. Existence of systematic $\Delta\alpha$ and $\Delta\delta$ type errors for all star type and in all catalogues is indicated.

1. INTRODUCTION

The Preliminary Compilation of DS-Programme Star Positions (PCDS) (Cvetković, 1992) contains 930 (right ascension) and 1225 (declination) stars with magnitudes from $6^m_.0$ to $9^m_.0$. Every star was observed approximately four times in the interval 1981 to 1987. The mean epochs of observation are 1982.91 in right ascension and 1983.19 in declination. The mean error in right ascension is $\pm0^s_.019\sec\delta$ and in declination $\pm0''_.27$.

It has to be borne in mind that the mean latitudes of observatories where the values in PCDS were determined is close to each one of the individual latitudes: Belgrade Observatory ($\varphi = +44^\circ48'$), Kiev ($\varphi = +50^\circ27'$), Kharkov ($\varphi = +50^\circ00'$), Odessa ($\varphi = +46^\circ29'$), Moscow ($\varphi = +55^\circ42'$) and Kazan ($\varphi = +55^\circ50'$).

The observations were made with the meridian circles and the results obtained by using the relative method. The positions of the stars in the catalogues are given in the FK4 system for the equinox B1950.0 and the epoch of observation. The data on the observational catalogues (Chernega et al., 1987; Golovko, 1982; Tauber, 1986; Myalkovskij, 1988; Pavlenko, 1989; Yatsenko et al., 1991; Sadžakov and Dačić, 1990) are given in Table 1 and those of PCDS in Table 2.

N in Table 1 stands for the total number of stars per catalogue; $\varepsilon_\alpha \cos\delta$, ε_δ denote rms errors of a single observation in right ascension and declination.

Table 1. Characteristics of the observational catalogues

catal.	coor.	per.obs.	N	$\varepsilon_\alpha \cos\delta$	ε_δ	dec.zone
Belgrade	α, δ	1981-1987	1571	$\pm 0^s.026$	$\pm 0''.34$	-30° to $+60^\circ$
Kiev	α, δ	1980-1984	986	± 0.027	± 0.46	+10 to +90
Kharkov	α	1980-1984	240	± 0.024	-	+50 to +70
Odessa	δ	1983-1985	250	-	± 0.38	−10 to +10
Moscow 1	δ	1981-1983	313	-	± 0.30	0 to +90
Moscow 2	δ	1981-1982	319	-	± 0.33	0 to +90
Kazan	δ	1981-1987	644	-	± 0.45	+30 to +90

Table 2. Rms errors in 10° zones in the PCDS

zones	N_α	$\varepsilon_\alpha \cos\delta$	N_δ	ε_δ
-10° to 0°	-	-	99	$\pm 0''.37$
0 to +10	-	-	144	± 0.39
+10 to +20	171	$\pm 0^s.024$	174	± 0.28
+20 to +30	155	± 0.019	156	± 0.27
+30 to +40	184	± 0.019	192	± 0.22
+40 to +50	174	± 0.021	183	± 0.21
+50 to +60	132	± 0.017	132	± 0.22
+60 to +70	103	± 0.013	103	± 0.24
$\delta > +70$	11	± 0.014	42	± 0.37

In the comparison of these catalogues we used the proper motions from the AGK3.

2. COMPARISON OF STAR POSITIONS

In order to obtain an insight into the PCDS quality as realistic as possible one should uncover the sources of the systematic influences. Let us start from the comparisons between the basic PCDS and each one of the individual catalogues used in its compilation. The following simple relation will be used

$$\Delta\alpha = \alpha_{PCDS} - \alpha_{CAT} =$$

$$= \Delta\alpha_o + \Delta\alpha_\delta + \Delta\alpha_\alpha + \Delta\alpha_m + \Delta\alpha_{sp}$$

$$\Delta\delta = \delta_{PCDS} - \delta_{CAT} =$$

$$= \Delta\delta_o + \Delta\delta_\delta + \Delta\delta_\alpha + \Delta\delta_m + \Delta\delta_{sp} \qquad (1)$$

where CAT means respectively – Belgrade, Kiev, Kazan, Kharkov, Odessa, Moscow 1 and Moscow 2. The obtained values are presented in Tables 3 to 10.

The systematic effects of the type $(\Delta\alpha_o+\Delta\alpha_\delta)$ and $(\Delta\delta_o+\Delta\delta_\delta)$ were first singled out and numerical values were formed for individual segments of the sky. The values $(\Delta\alpha_o+\Delta\alpha_\delta)$ vary from $-0^s.006$ to $+0^s.008$, $(\Delta\delta_o+\Delta\delta_\delta)$ vary from $-0''.49$ to $+0''.34$ and the errors of determination for all the catalogues vary from $\pm 0^s.002$ to $\pm 0^s.003$, resp. $\pm 0''.02$ to $\pm 0''.09$. These values were calculated with weights on the basis of the number of stars in each interval. The values $(\Delta\alpha_o+\Delta\alpha_\delta)$ and $(\Delta\delta_o+\Delta\delta_\delta)$ are predominatly of negative sign.

Table 3. Systematic effects of the type $(\Delta\alpha_o+\Delta\alpha_\delta)$ according to declination zones

	PCDS-Belgrade			PCDS-Kiev			PCDS-Kharkov		
zone	$\Delta\alpha_o+\Delta\alpha_\delta$	$\varepsilon_\alpha \cos\delta$	N	$\Delta\alpha_o+\Delta\alpha_\delta$	$\varepsilon_\alpha \cos\delta$	N	$\Delta\alpha_o+\Delta\alpha_\delta$	$\varepsilon_\alpha \cos\delta$	N
$+10^\circ$ to $+20^\circ$	$-0^s.001$	$\pm 0^s.002$	168	$+0^s.002$	$\pm 0^s.002$	170			
+20 to +30	−0.003	±0.002	154	+0.003	±0.002	155			
+30 to +40	−0.006	±0.002	182	+0.005	±0.002	184			
+40 to +50	−0.003	±0.002	170	+0.003	±0.002	171			
+50 to +60	+0.008	±0.003	122	+0.001	±0.002	131	$-0^s.005$	$\pm 0^s.002$	135
+60 to +90	+0.002	±0.003	105	−0.002	±0.002	114	−0.000	±0.002	103

Table 4. Systematic effects of the type $(\Delta\delta_o+\Delta\delta_\delta)$ according to declination zones

	PCDS-Belgrade			PCDS-Kiev			PCDS-Odessa		
zone	$\Delta\delta_o+\Delta\delta_\delta$	ε_δ	N	$\Delta\delta_o+\Delta\delta_\delta$	ε_δ	N	$\Delta\delta_o+\Delta\delta_\delta$	ε_δ	N
-10^o to 0^o	$-0''.02$	$\pm0''.04$	111				$+0''.02$	$\pm0''.05$	111
0 to +10	−0.12	±0.04	132				+0.15	±0.04	131
+10 to +20	−0.09	±0.04	173	$+0''.04$	$\pm0''.02$	173			
+20 to +30	−0.06	±0.04	155	−0.01	±0.02	156			
+30 to +40	−0.13	±0.04	181	−0.07	±0.02	189			
+40 to +50	−0.06	±0.04	175	−0.06	±0.02	180			
+50 to +60	+0.03	±0.05	128	−0.07	±0.03	131			
+60 to +90	+0.13	±0.05	106	+0.13	±0.03	145			
	PCDS-Moscow 1			PCDS-Moscow 2			PCDS-Kazan		
zone	$\Delta\delta_o+\Delta\delta_\delta$	ε_δ	N	$\Delta\delta_o+\Delta\delta_\delta$	ε_δ	N	$\Delta\delta_o+\Delta\delta_\delta$	ε_δ	N
0^o to $+10^o$	$-0''.14$	$\pm0''.08$	9	$-0''.17$	$\pm0''.06$	9			
+10 to +20	−0.32	±0.07	12	−0.27	±0.06	14			
+20 to +30	−0.23	±0.09	15	−0.19	±0.06	15			
+30 to +40	+0.33	±0.04	83	+0.34	±0.03	80	$+0''.18$	$\pm0''.03$	194
+40 to +50	+0.04	±0.04	83	+0.01	±0.04	89	+0.12	±0.03	178
+50 to +60	−0.41	±0.04	58	−0.49	±0.03	59	+0.04	±0.04	128
+60 to +90	−0.12	±0.05	49	−0.12	±0.04	50	−0.26	±0.04	141

Upon eliminating $(\Delta\alpha_o+\Delta\alpha_\delta)$ and $(\Delta\delta_o+\Delta\delta_\delta)$ values, the values $\Delta\alpha_\alpha$ and $\Delta\delta_\alpha$ were obtained by means of the formula:

$$\Delta\alpha_\alpha = \Delta\alpha - (\Delta\alpha_o + \Delta\alpha_\delta);$$

$$\Delta\delta_\alpha = \Delta\delta - (\Delta\delta_o + \Delta\delta_\delta), \qquad (2)$$

with the mean errors of determination: $\pm0^s.002$ and $\pm0''.04$ (see Tables 5 and 6).

The values $\Delta\alpha_\alpha$ vary from $-0^s.007$ to $+0^s.009$ and $\Delta\delta_\alpha$ vary from $-0''.18$ to $+0''.15$ in individual segments of the sky. The curve representing the mean values of $\Delta\alpha_\alpha$ and $\Delta\delta_\alpha$ in the four hours zones takes a sinusoidal form. In the zone 0^h to 12^h in right ascension, the values $\Delta\alpha_\alpha$ are $-0^s.006$ to $+0^s.009$, and from 12^h to 24^h they are $-0^s.007$ to $+0^s.006$; from 0^h to 12^h in right ascension, the values $\Delta\delta_\alpha$ are $-0''.09$ to $+0''.13$, and from 12^h to 24^h they are $-0''.15$ to $+0''.18$ (see Fig.3 and Fig 4).

Considering that in the observations for the catalogues the screen grids were not used, the search for systematic effects of the type $\Delta\alpha_m$ and $\Delta\delta_m$ is justified. These values have been obtained by means of the formula:

$$\Delta\alpha_m = \Delta\alpha - (\Delta\alpha_o + \Delta\alpha_\delta + \Delta\alpha_\alpha);$$

$$\Delta\delta_m = \Delta\delta - (\Delta\delta_o + \Delta\delta_\delta + \Delta\delta_\alpha) \qquad (3)$$

and are given in Table 7 and Table 8.

The values $\Delta\alpha_m$ vary from $-0^s.003$ to $+0^s.003$, $\Delta\delta_m$ vary from $-0''.12$ to $+0''.11$. The obtained values are notable solely in the case of Moscow 1 and Moscow 2 whereas for the other catalogues they are uncertain (see Fig.5 and Fig.6).

The values of the $\Delta\alpha_{sp}$ and $\Delta\delta_{sp}$ type errors were obtained by elimination of foregoing systematic effects from differences of right ascensions and declinations of stars common to both catalogues:

$$\Delta\alpha_{sp} = \Delta\alpha - (\Delta\alpha_o + \Delta\alpha_\delta + \Delta\alpha_\alpha + \Delta\alpha_m);$$

$$\Delta\delta_{sp} = \Delta\delta - (\Delta\delta_o + \Delta\delta_\delta + \Delta\delta_\alpha + \Delta\delta_m) \ . \qquad (4)$$

Table 5. Systematic effects of the type $\Delta\alpha_\alpha$ according to right ascension zones

	PCDS-Belgrade			PCDS-Kiev			PCDS-Kharkov		
α	$\Delta\alpha_\alpha$	$\varepsilon_\alpha \cos\delta$	N	$\Delta\alpha_\alpha$	$\varepsilon_\alpha \cos\delta$	N	$\Delta\alpha_\alpha$	$\varepsilon_\alpha \cos\delta$	N
0^h - 4^h	$+0^s.009$	$\pm0^s.002$	166	$-0^s.006$	$\pm0^s.002$	170	$-0^s.001$	$\pm0^s.003$	57
4 - 8	+0.004	±0.002	188	−0.004	±0.002	190	+0.000	±0.004	35
8 - 12	−0.002	±0.003	88	+0.001	±0.002	93	+0.004	±0.003	27
12 - 16	−0.005	±0.003	81	+0.001	±0.003	85	+0.001	±0.003	21
16 - 20	−0.003	±0.002	172	+0.002	±0.002	177	+0.002	±0.004	32
20 - 24	−0.007	±0.002	206	+0.006	±0.001	210	−0.002	±0.003	66

Table 6. Systematic effects of the type $\Delta\delta_\alpha$ according to right ascension zones

	PCDS-Belgrade			PCDS-Kiev			PCDS-Odessa		
α	$\Delta\delta_\alpha$	ε_δ	N	$\Delta\delta_\alpha$	ε_δ	N	$\Delta\delta_\alpha$	ε_δ	N
0^h - 4^h	$-0''.06$	$\pm0''.04$	197	$+0''.03$	$\pm0''.02$	181	$+0''.00$	$\pm0''.11$	30
4 - 8	−0.09	±0.03	252	+0.02	±0.02	194	+0.13	±0.07	63
8 - 12	+0.04	±0.05	128	−0.04	±0.03	99	−0.01	±0.08	34
12 - 16	+0.15	±0.05	113	−0.06	±0.03	89	−0.18	±0.08	31
16 - 20	+0.02	±0.03	220	+0.01	±0.02	185	−0.05	±0.06	42
20 - 24	+0.03	±0.03	251	−0.00	±0.02	226	+0.00	±0.07	42
	PCDS-Moscow 1			PCDS-Moscow 2			PCDS-Kazan		
α	$\Delta\delta_\alpha$	ε_δ	N	$\Delta\delta_\alpha$	ε_δ	N	$\Delta\delta_\alpha$	ε_δ	N
0^h - 4^h	$-0''.02$	$\pm0''.05$	49	$+0''.05$	$\pm0''.04$	54	$-0''.03$	$\pm0''.04$	136
4 - 8	−0.00	±0.06	48	−0.02	±0.05	44	+0.03	±0.04	124
8 - 12	−0.00	±0.04	60	−0.04	±0.04	66	+0.10	±0.05	65
12 - 16	+0.05	±0.04	51	+0.04	±0.04	50	−0.09	±0.06	56
16 - 20	−0.07	±0.05	49	−0.08	±0.05	48	+0.04	±0.04	103
20 - 24	+0.05	±0.04	52	+0.05	±0.03	54	−0.04	±0.03	157

Table 7. Systematic effects of the type $\Delta\alpha_m$ according to magnitude

	PCDS-Belgrade			PCDS-Kiev			PCDS-Kharkov		
m	$\Delta\alpha_m$	$\varepsilon_\alpha \cos\delta$	N	$\Delta\alpha_m$	$\varepsilon_\alpha \cos\delta$	N	$\Delta\alpha_m$	$\varepsilon_\alpha \cos\delta$	N
$m < 7.0$	$+0^s.000$	$\pm0^s.002$	132	$+0^s.000$	$\pm0^s.002$	134	$+0^s.001$	$\pm0^s.004$	28
7.0 - 7.5	+0.000	±0.003	118	−0.002	±0.002	121	+0.002	±0.003	29
7.5 - 8.0	+0.003	±0.002	149	−0.002	±0.002	152	−0.003	±0.002	43
8.0 - 8.5	−0.003	±0.002	231	+0.003	±0.001	234	+0.003	±0.002	63
$m > 8.5$	+0.001	±0.002	271	−0.001	±0.001	284	−0.002	±0.003	75

Table 8. Systematic effects of the type $\Delta\delta_m$ according to magnitude

	PCDS-Belgrade			PCDS-Kiev			PCDS-Odessa		
m	$\Delta\delta_m$	ε_δ	N	$\Delta\delta_m$	ε_δ	N	$\Delta\delta_m$	ε_δ	N
$m < 7.0$	+0$''$.02	±0$''$.04	180	+0$''$.02	±0$''$.02	142	−0$''$.02	±0$''$.08	46
7.0 - 7.5	−0.12	±0.04	159	−0.01	±0.03	128	+0.11	±0.07	40
7.5 - 8.0	+0.02	±0.04	192	−0.01	±0.02	159	−0.06	±0.07	44
8.0 - 8.5	+0.01	±0.03	282	+0.02	±0.02	247	+0.00	±0.07	49
$m > 8.5$	+0.02	±0.03	348	−0.02	±0.02	298	−0.02	±0.06	63
	PCDS-Moscow 1			PCDS-Moscow 2			PCDS-Kazan		
m	$\Delta\delta_m$	ε_δ	N	$\Delta\delta_m$	ε_δ	N	$\Delta\delta_m$	ε_δ	N
$m < 7.0$	−0$''$.04	±0$''$.05	53	−0$''$.05	±0$''$.04	54	−0$''$.03	±0$''$.05	86
7.0 - 7.5	+0.07	±0.04	50	+0.04	±0.05	51	+0.02	±0.05	82
7.5 - 8.0	−0.02	±0.04	59	−0.03	±0.04	58	+0.01	±0.04	114
8.0 - 8.5	+0.01	±0.04	80	−0.02	±0.03	80	−0.00	±0.03	166
$m > 8.5$	−0.02	±0.04	67	+0.05	±0.04	73	+0.00	±0.03	193

Table 9. Systematic effects of the type $\Delta\alpha_{sp}$ according to spectral type

	PCDS-Belgrade			PCDS-Kiev			PCDS-Kharkov		
Sp	$\Delta\alpha_{sp}$	$\varepsilon_\alpha \cos\delta$	N	$\Delta\alpha_{sp}$	$\varepsilon_\alpha \cos\delta$	N	$\Delta\alpha_{sp}$	$\varepsilon_\alpha \cos\delta$	N
O,B,A	+0^s.000	±0^s.001	348	+0^s.001	±0^s.001	352	−0^s.002	±0^s.001	88
F	+0.001	±0.001	246	−0.000	±0.001	256	−0.001	±0.001	71
G	−0.001	±0.002	125	+0.000	±0.001	126	+0.001	±0.001	26
K,M,N	+0.002	±0.002	113	−0.003	±0.002	115	−0.000	±0.001	34

Table 10. Systematic effects of the type $\Delta\delta_{sp}$ according to spectral type

	PCDS-Belgrade			PCDS-Kiev			PCDS-Odessa		
Sp	$\Delta\delta_{sp}$	ε_δ	N	$\Delta\delta_{sp}$	ε_δ	N	$\Delta\delta_{sp}$	ε_δ	N
O,B,A	−0$''$.00	±0$''$.02	447	−0$''$.02	±0$''$.02	356	+0$''$.00	±0$''$.04	94
F	−0.01	±0.03	316	+0.01	±0.02	257	+0.00	±0.06	61
G	+0.02	±0.04	166	−0.01	±0.03	131	−0.17	±0.08	37
K,M,N	+0.03	±0.05	128	−0.04	±0.03	115	+0.21	±0.13	17
	PCDS-Moscow 1			PCDS-Moscow 2			PCDS-Kazan		
Sp	$\Delta\delta_{sp}$	ε_δ	N	$\Delta\delta_{sp}$	ε_δ	N	$\Delta\delta_{sp}$	ε_δ	N
O,B,A	−0$''$.05	±0$''$.03	96	−0$''$.02	±0$''$.03	94	+0$''$.05	±0$''$.03	239
F	−0.03	±0.03	107	−0.02	±0.03	112	+0.02	±0.03	173
G	+0.02	±0.05	53	−0.04	±0.03	54	+0.01	±0.05	81
K,M,N	+0.13	±0.05	35	+0.09	±0.05	35	−0.08	±0.05	71

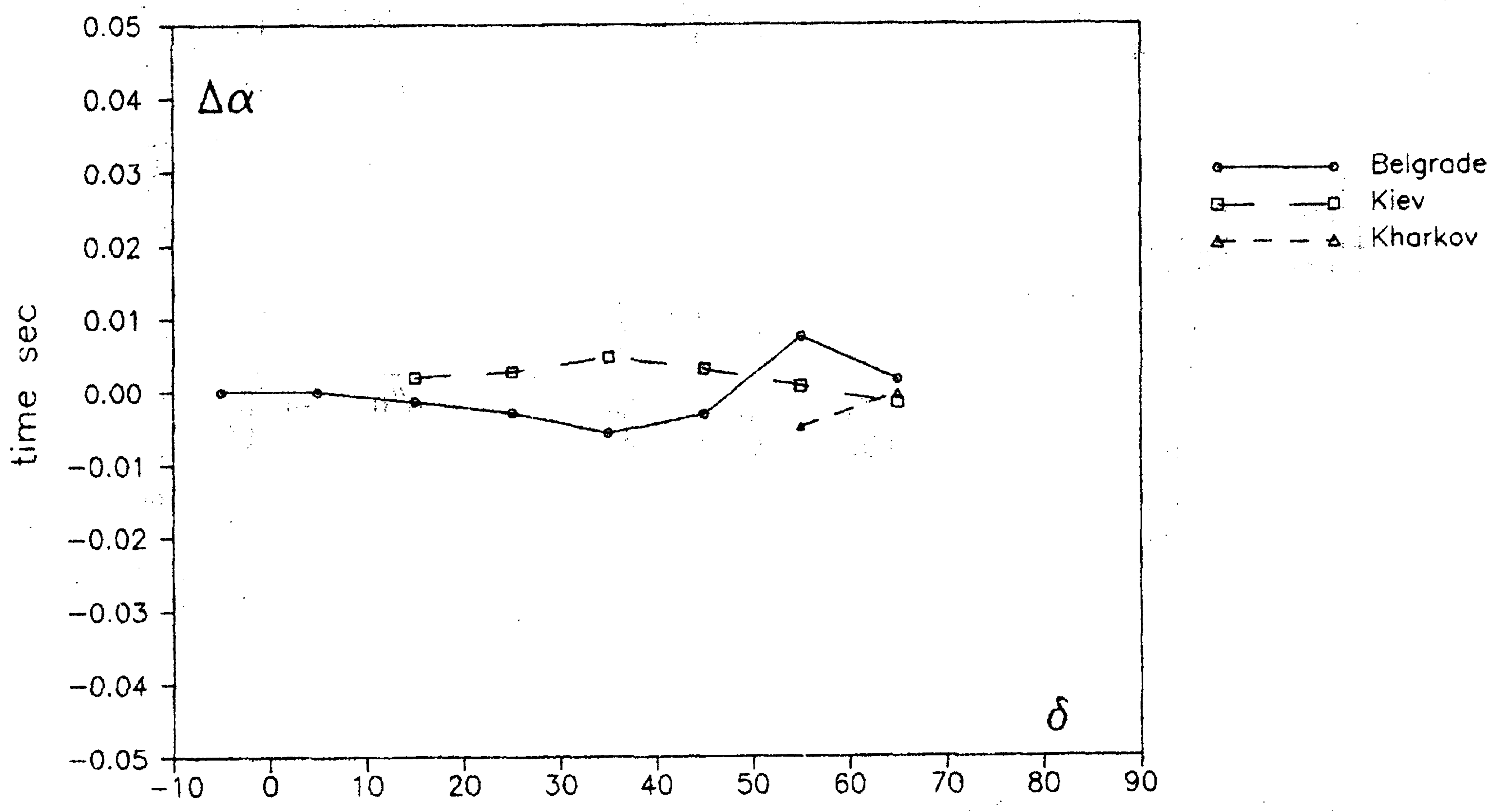

Fig.1. Systematic errors $\Delta\alpha = \alpha_{PCDS} - \alpha_{CAT}$ according to declination δ (PCDS – Preliminary Compilation of DS-Programme Star Positions; catalogues (CAT) – Belgrade, Kiev, Kharkov).

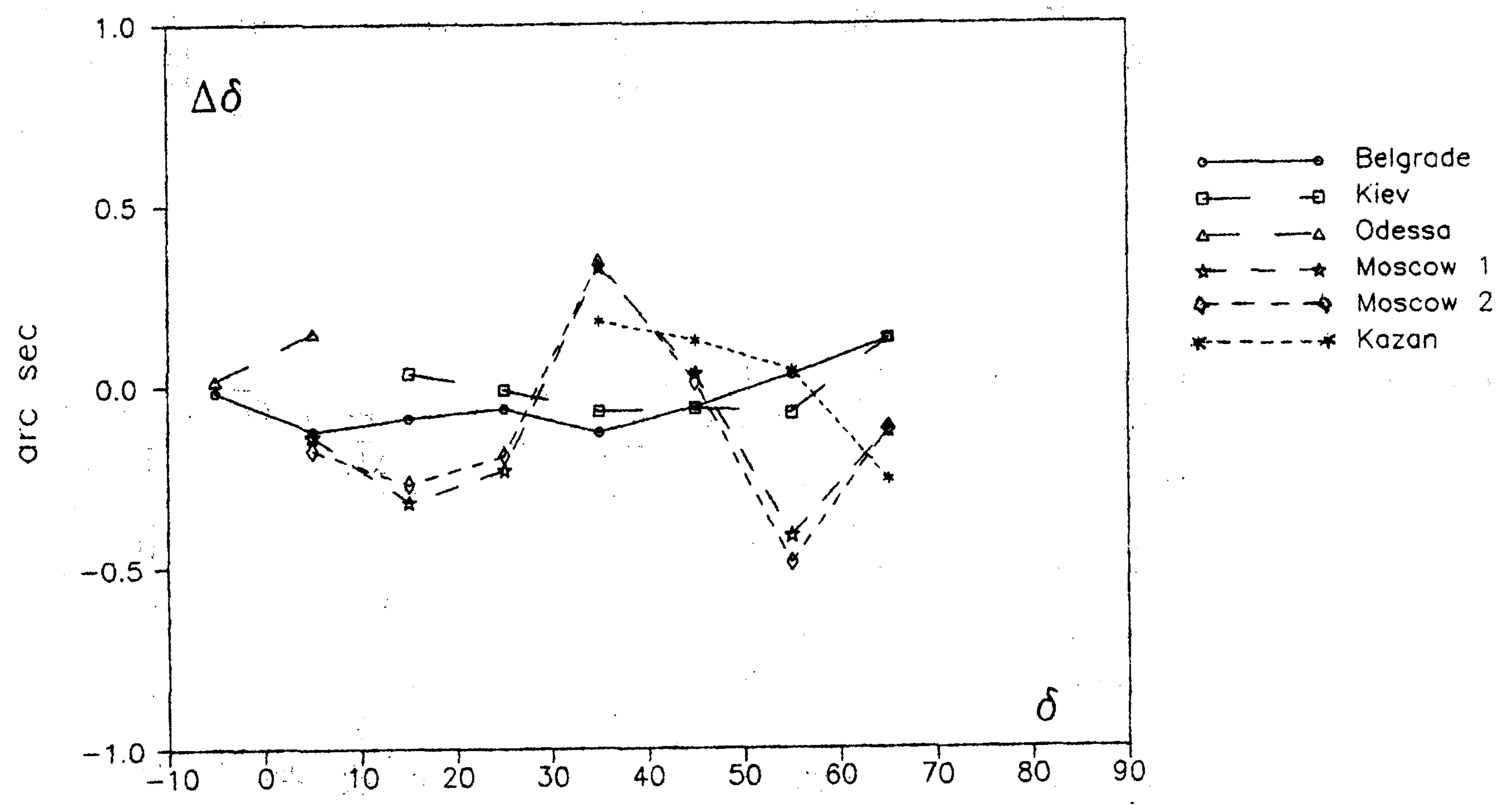

Fig.2. Systematic errors $\Delta\delta = \delta_{PCDS} - \delta_{CAT}$ according to declination δ (CAT – Belgrade, Kiev, Odessa, Moscow 1, Moscow 2, Kazan).

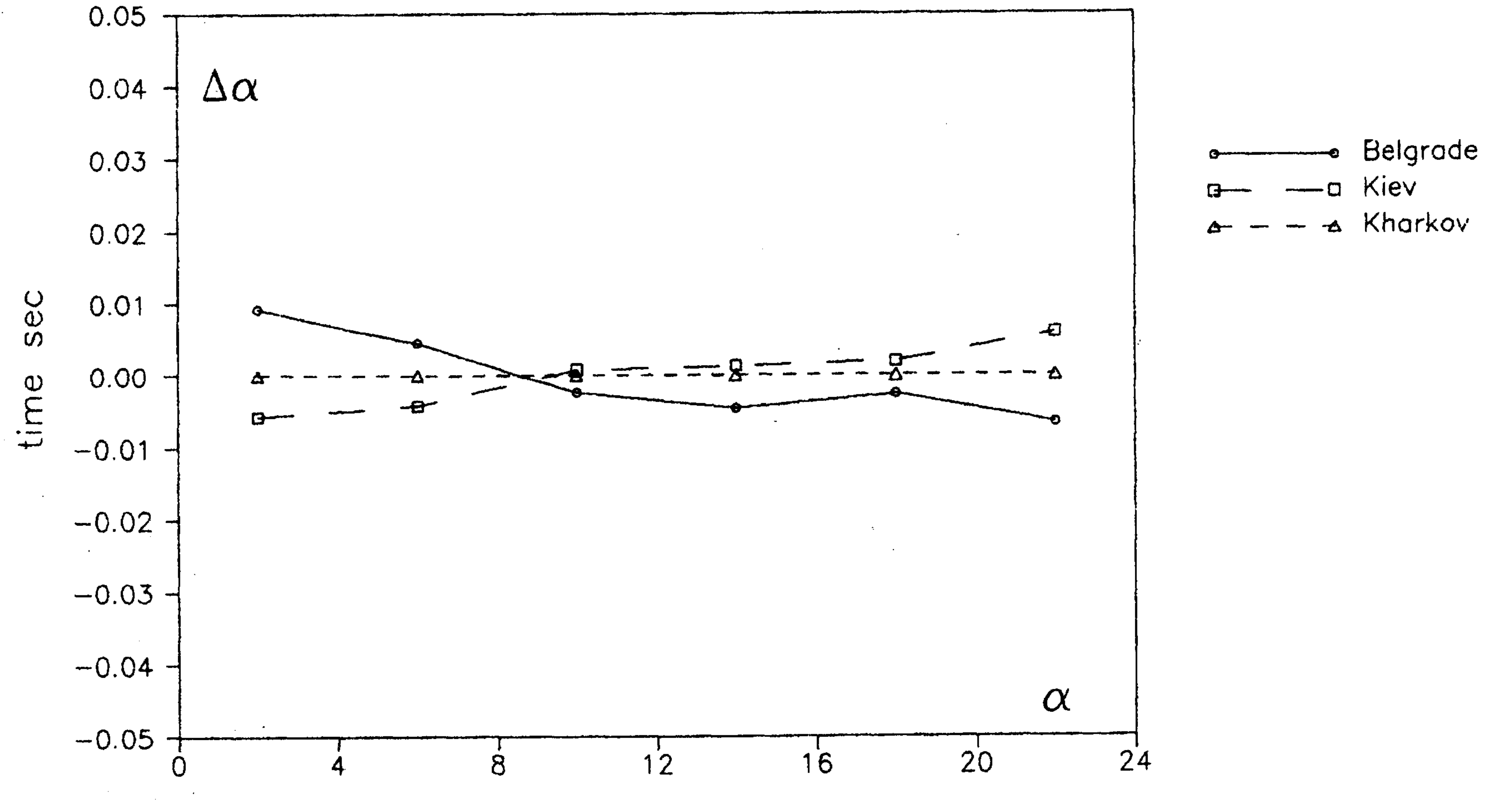

Fig.3. Systematic errors $\Delta\alpha = \alpha_{PCDS} - \alpha_{CAT}$ according to right ascension α (CAT – Belgrade, Kiev, Kharkov).

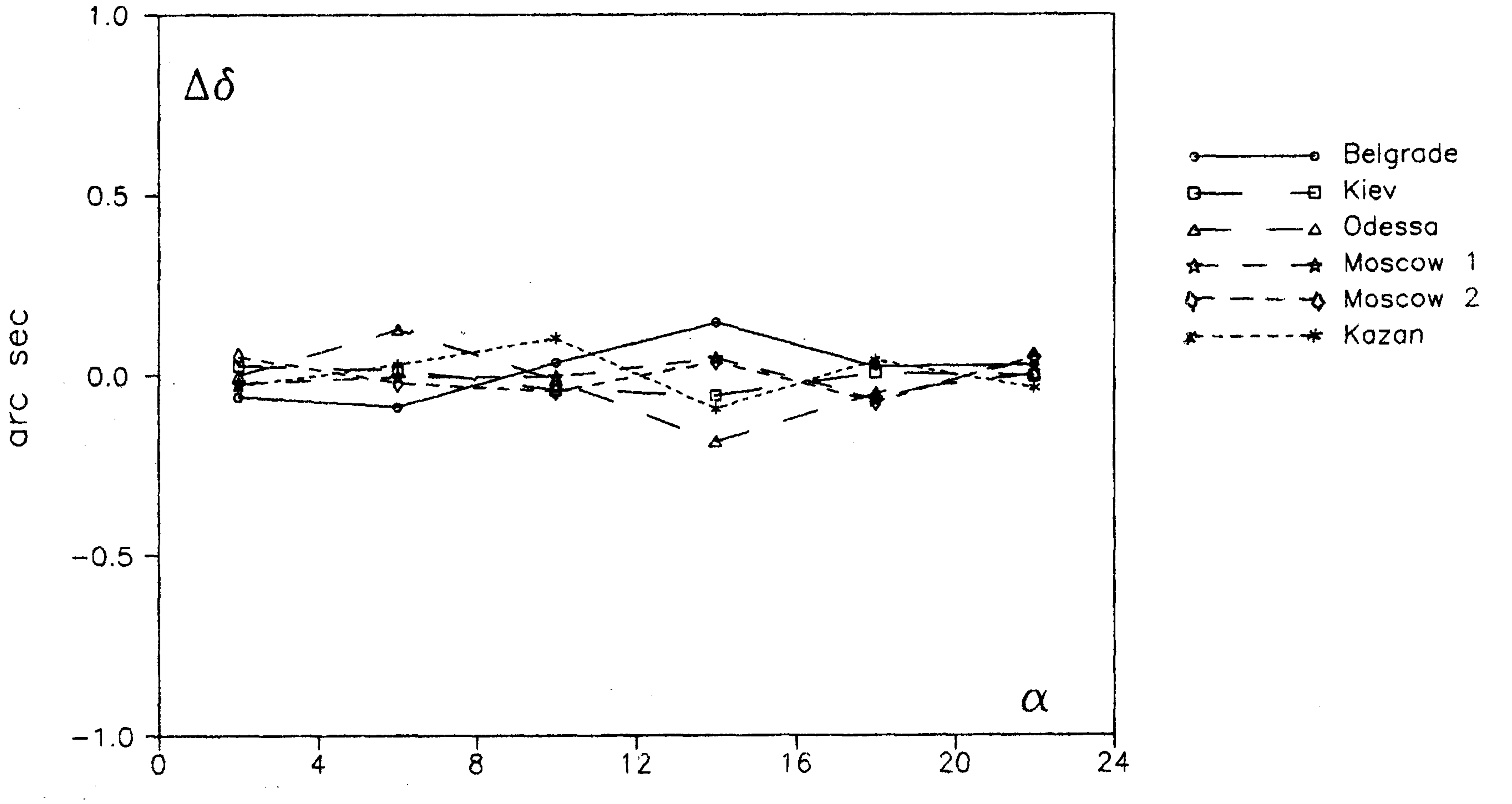

Fig.4. Systematic errors $\Delta\delta = \delta_{PCDS} - \delta_{CAT}$ according to right ascension α (CAT – Belgrade, Kiev, Odessa, Moscow 1, Moscow 2, Kazan).

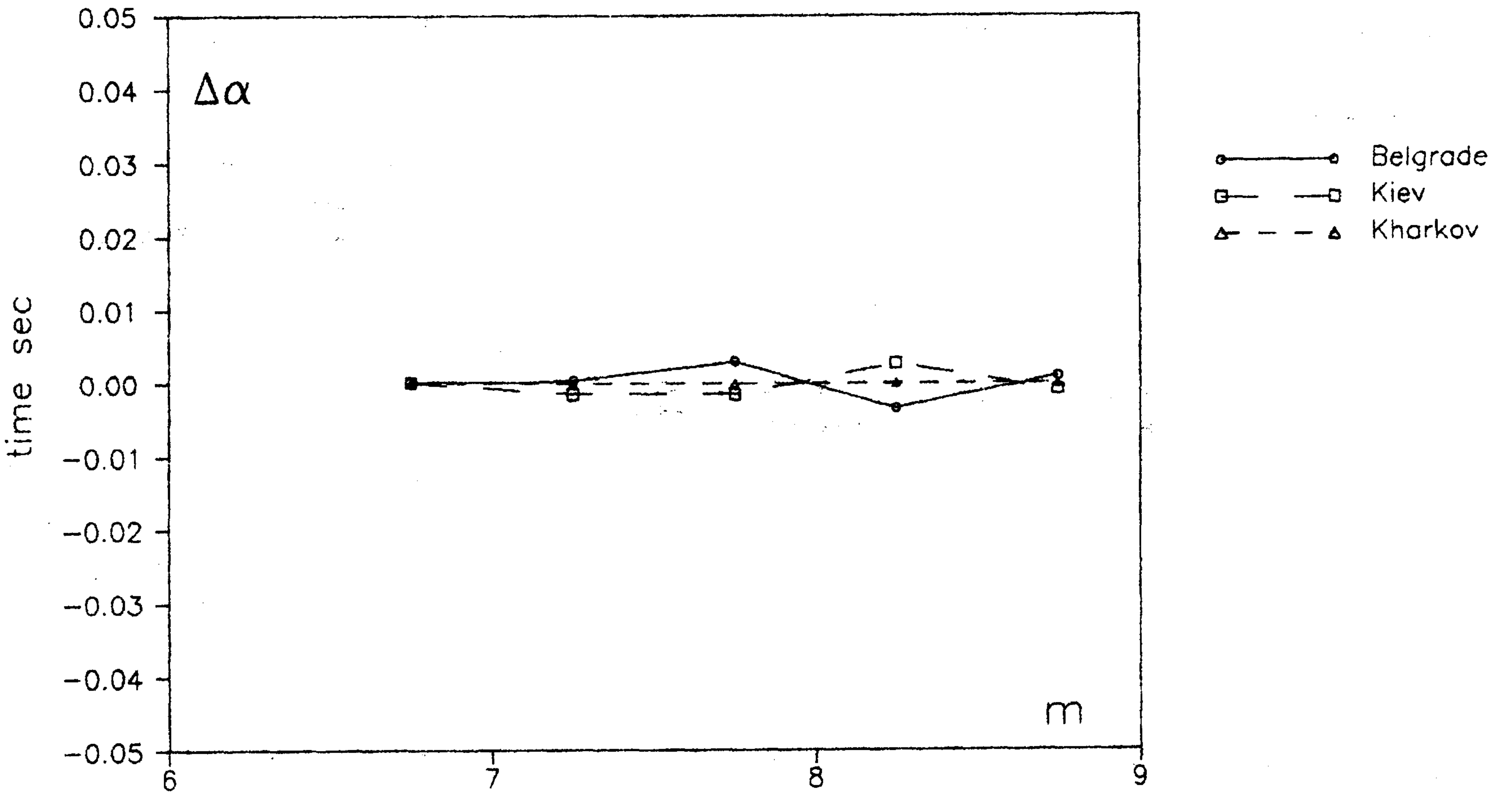

Fig.5. Systematic errors $\Delta\alpha = \alpha_{PCDS} - \alpha_{CAT}$ according to apparent magnitude m (CAT – Belgrade, Kiev, Kharkov).

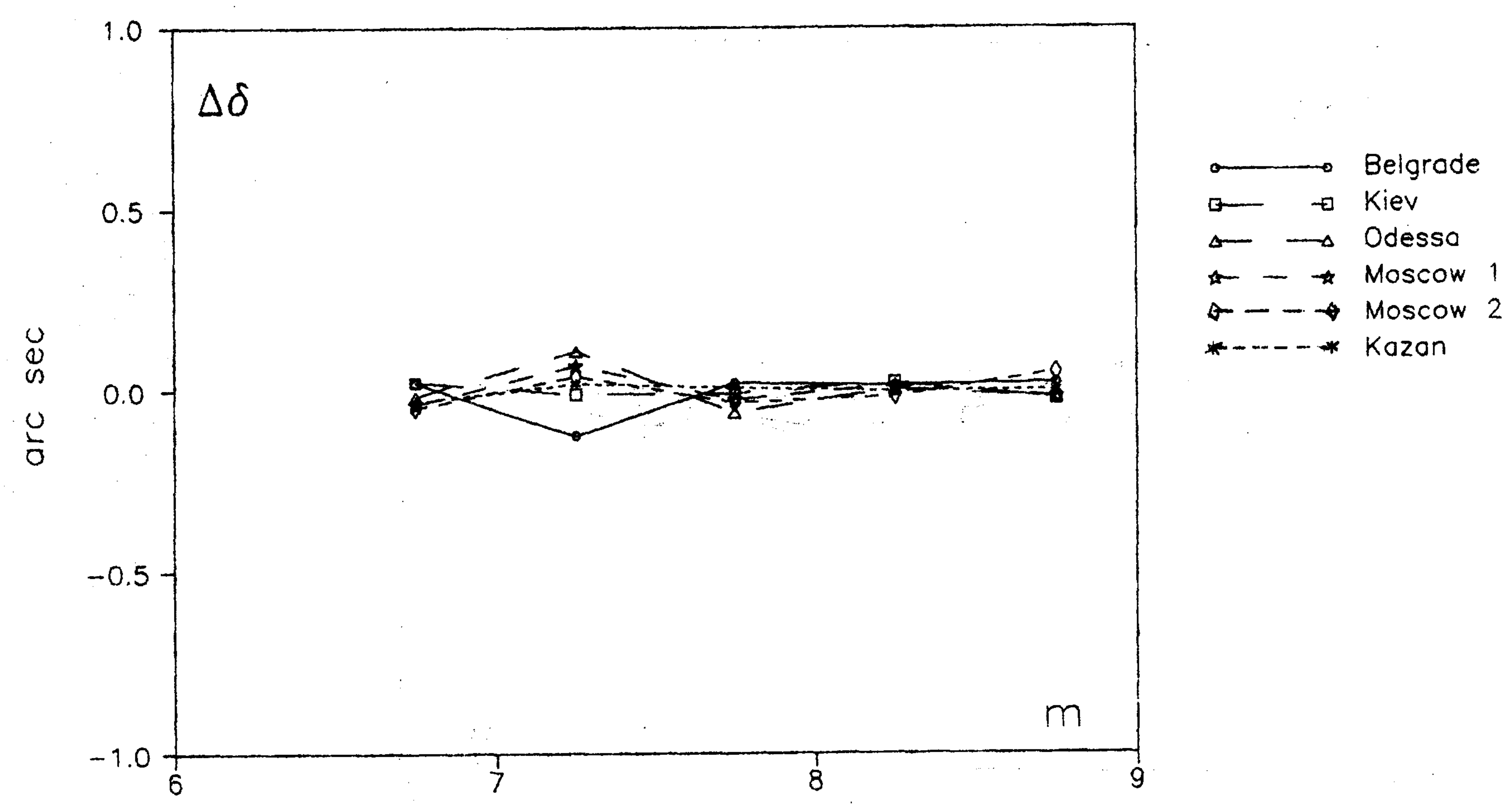

Fig.6. Systematic errors $\Delta\delta = \delta_{PCDS} - \delta_{CAT}$ according to apparent magnitude m (CAT – Belgrade, Kiev, Odessa, Moscow 1, Moscow 2, Kazan).

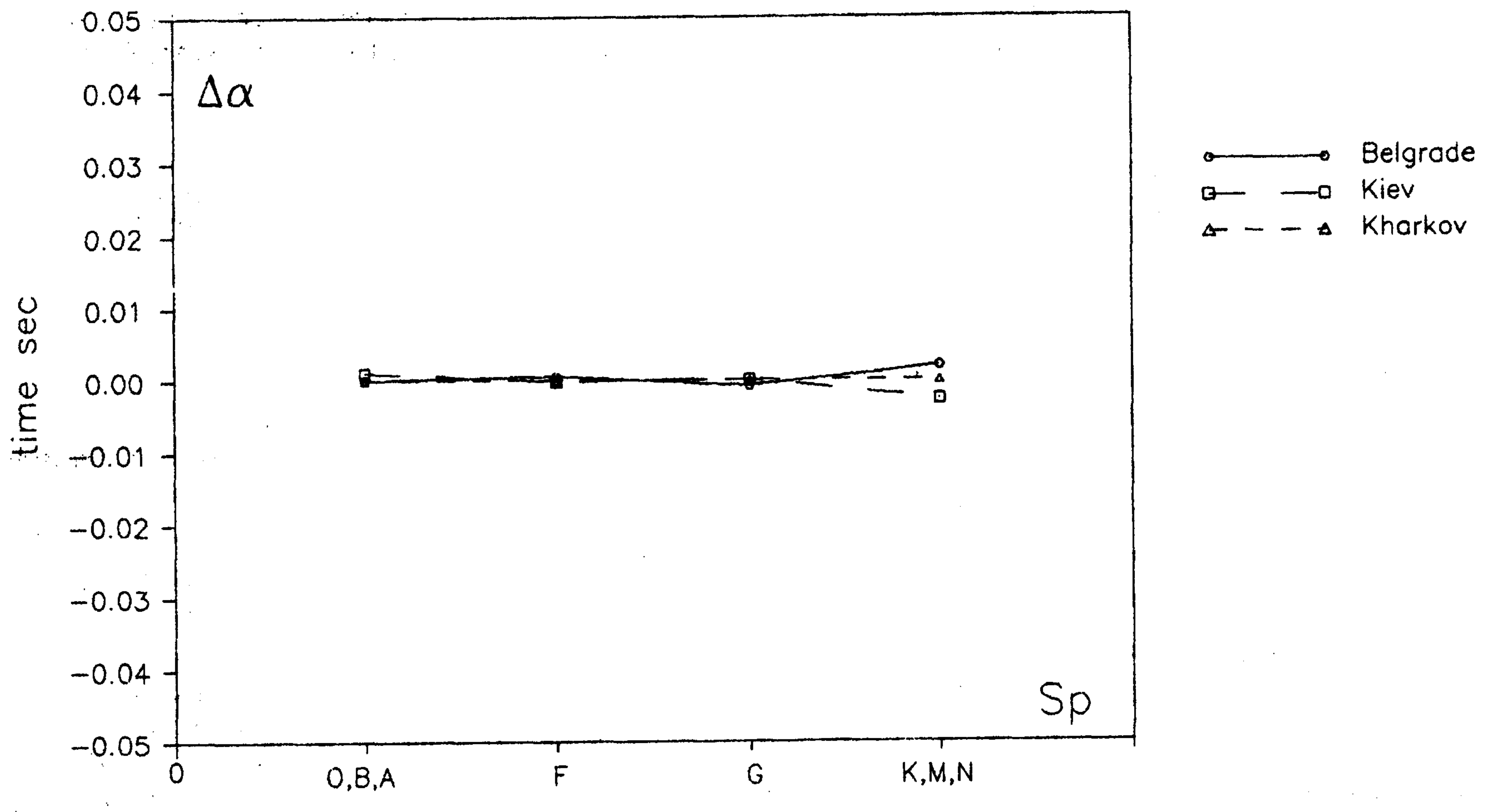

Fig.7. Systematic errors $\Delta\alpha = \alpha_{PCDS}$ - α_{CAT} according to spectral type Sp (CAT – Belgrade, Kiev, Kharkov).

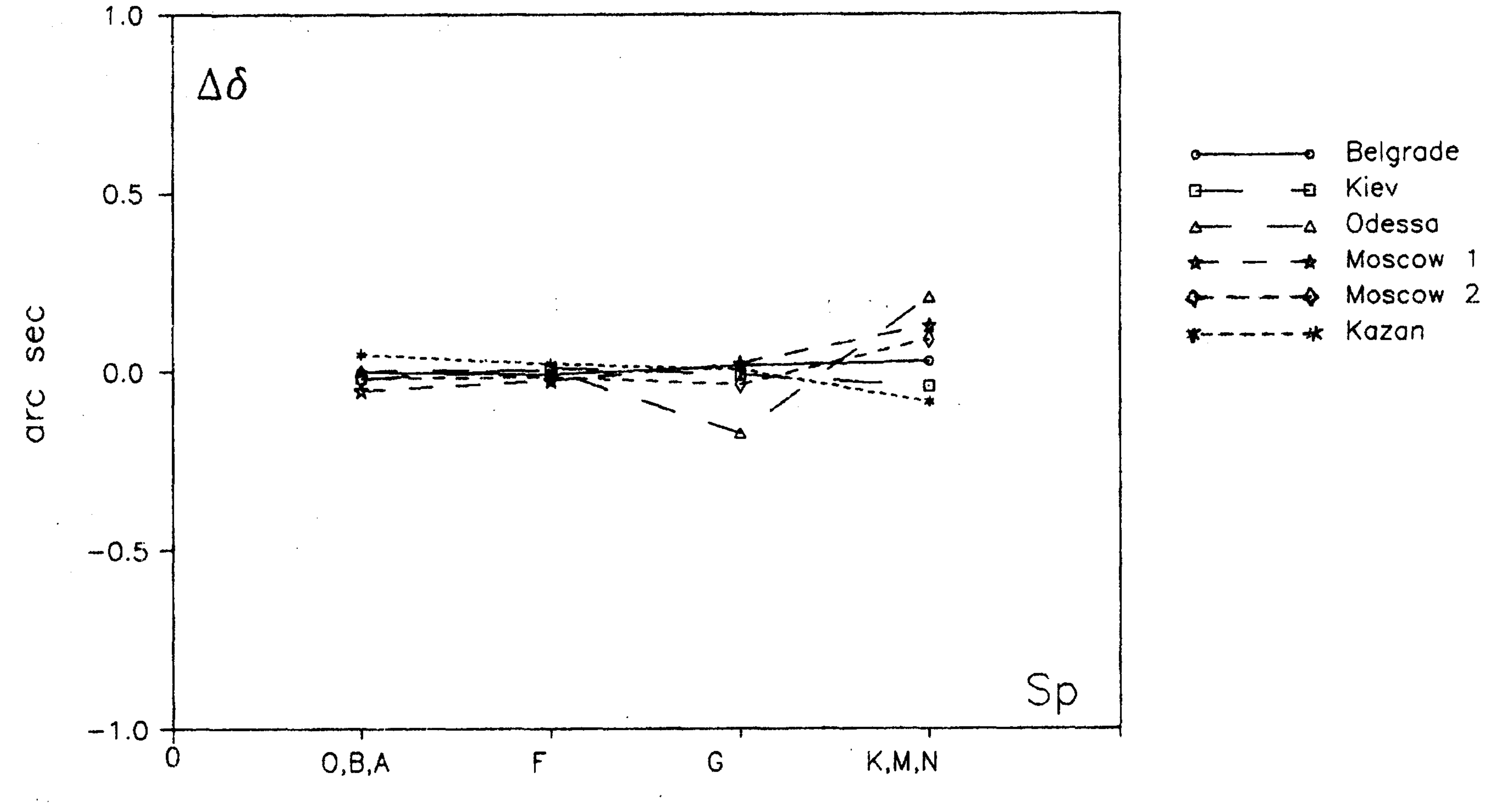

Fig.8. Systematic errors $\Delta\delta = \delta_{PCDS}$ - δ_{CAT} according to spectral type Sp (CAT – Belgrade, Kiev, Odessa, Moscow 1, Moscow 2, Kazan).

The obtained $\Delta\alpha_{sp}$ and $\Delta\delta_{sp}$ values are grouped by spectral type (see Table 9 and Table 10) as follows:

A - all stars of the spectral type A0 to A9, including also some stars of the spectral type B and O;
F - all stars of the spectral type F0 to F9;
G - all stars of the spectral type G0 to G9;
K - all stars of the spectral type K0 to K9, including some stars of the spectral type M and N.

The analysis shows that the stars of different spectral types exhibit different $\Delta\alpha_{sp}$ and $\Delta\delta_{sp}$ values (see Fig.7 and Fig.8).

3. CONCLUSION

On the basis of the above laid out, we can say that systematic effects of $\Delta\alpha_\delta$, $\Delta\delta_\delta$, $\Delta\alpha_\alpha$, $\Delta\delta_\alpha$ types are evident and, most probably, they result from:

1. seasonal systematic errors;
2. possible systematic errors in proper motions;
3. systematic errors resulting from observations of right ascensions and declinations, made by zones;
4. systematic errors of $\Delta\alpha_m$ and $\Delta\delta_m$ types are evident especially $\Delta\delta_m$ for stars whose apparent magnitude is about $7^m\!.0$ to $7^m\!.5$.

The systematic errors of $\Delta\delta_{sp}$ types are the largest for stars of spectral types G,K,M,N.

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СИСТЕМАТСКЕ ГРЕШКЕ ПОСМАТРАЧКИХ КАТАЛОГА ДВОЈНИХ ЗВЕЗДА

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Поређење Прелиминарне компилације положаја звезда DS програма (PCDS) са каталозима двојних звезда (Београд, Киев, Харков, Одеса, Москва 1, Москва 2, Казан) урађено је по ректасцензији, деклинацији, магнитуди и спектралном типу. Постојање систематских грешака $\Delta\alpha$ и $\Delta\delta$ за све типове звезда уочава се у свим каталозима.