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METHODS OF SMOOTHING APPLIED TO DIFFERENCES IN STAR POSITIONS IN OBSERVATIONAL CATALOGUES

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SUMMARY: Three different methods, Whittaker - Robinson - Vondrak (WRV), cubic spline (SPL) and Expansion of the Elementary Trigonometric and Exponential Functions (ETE), are applied to differences in star positions of five observational catalogues in order to eliminate random errors. The Belgrade, Kiev, Moscow, Odessa and Kharkov catalogues of double stars (DS) programme have been used. The ETE method appears as reliable and even somewhat more efficacious that the usual WRV and SPL methods.

1. INTRODUCTION

The observational results contain, in addition to systematic, the unavoidable random errors as well, making those results differing among themselves in an random manner. By their nature the random errors display a normal probability distribution and mutual compensating property. Their effect is therefore getting ever smaller with the the number of observations getting larger. On the other hand the systematic errors must be carefully investigated in order to eliminate, or at least to lessen, their effect.

By using the metods of smoothing the impact of errors on the quantities considered is being minimized. These methods involve the calculation of parameters of some function whose class is often subjectively and erroneously determined. Consequently the possibility is present of failing to achieve the necessary efficacity of the smoothing. This is why the flexible methotds of smoothing are being used such as WRV (Vondrak 1969 and 1976) and SPL (Reinsch 1967). The flexible methods are being "adapted" to the measured quantities (important when the class of the function used for the smoothing is not known). The smoothing effected by these methods reduces to the segment approximation of the function considered by the third power polynomial.

In the present paper the application is made of these two methods along with the method ETE authored by B. Jovanović (1987). The latter method might be qualified as belonging to the mean quadratic, nonlinear type approximation. This method makes it possible to approximate any arbitrary given function with equidistant argument by the sum of elementary functions defined by a special linear recurrent second order relation.

These methods have been applied for smoothing the differeces in star positions (differences in right ascension and declination) as given in five observational catalogues of DS programme. By comparing the results obtained an esimate of the efficiency of these methods was provided.

The following observational catalogues have been used: Belgrade (Sadžakov and Dačić 1990) and Kiev (Chernega et al. 1987), containing both right ascensions and declination, Moscow (Tauber 1986) and Odessa (Myalkoskij 1988) with declinations and Kharkov catalogue (Pavlenko 1989) with right ascensions of DS stars.

The positions in all of these catalogues are given in the FK4 system for the equinox B1950.0 and for the epoch of observation.

2. DATA TREATMENT

The star position in the catalogues being given for different epochs it was necessary first to reduce all these positions to one and the same epoch. That reduction has been made for the epoch 1950.0. The Belgrade catalogue has been taken as the basic one at the calculation of the position differences in consideration at the fact that it contains the largest number of common stars with the rest of catalogues.

The number (N) of stars in catalogues, the number of common stars in right ascension (N_α), declination (N_δ), and declination zones are given in Table 1.

Table 1. Particulars concerning catalogues and stars used

CATALOGUE	N	N_α	N_δ	Declination zone
BELGRADE	1570	–	–	$-30^o - +60^o$
KIEV	985	814	902	$+10 - +90$
MOSCOW	313	–	274	$0 - +90$
ODESSA	250	–	221	$-10 - +10$
KHARKOV	239	171	–	$+50 - +70$

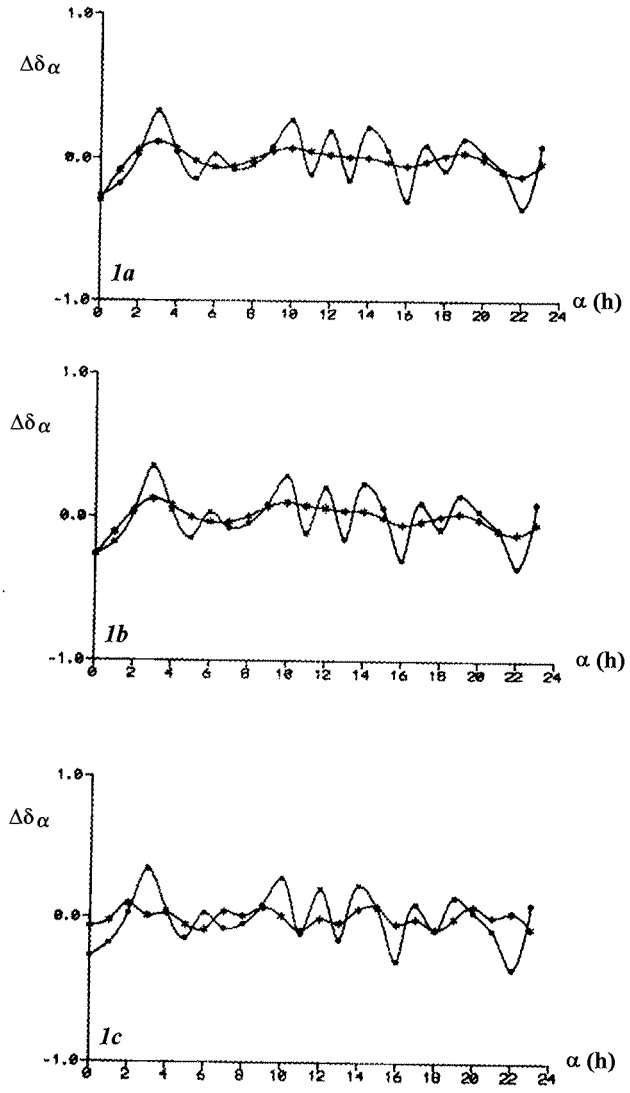


Fig. 1. *Smooting the differences $\Delta\delta_\alpha$ between the Belgrade and Moscow catalogues (pointed curve): a) WRV, b) SPL i c) ETE.*

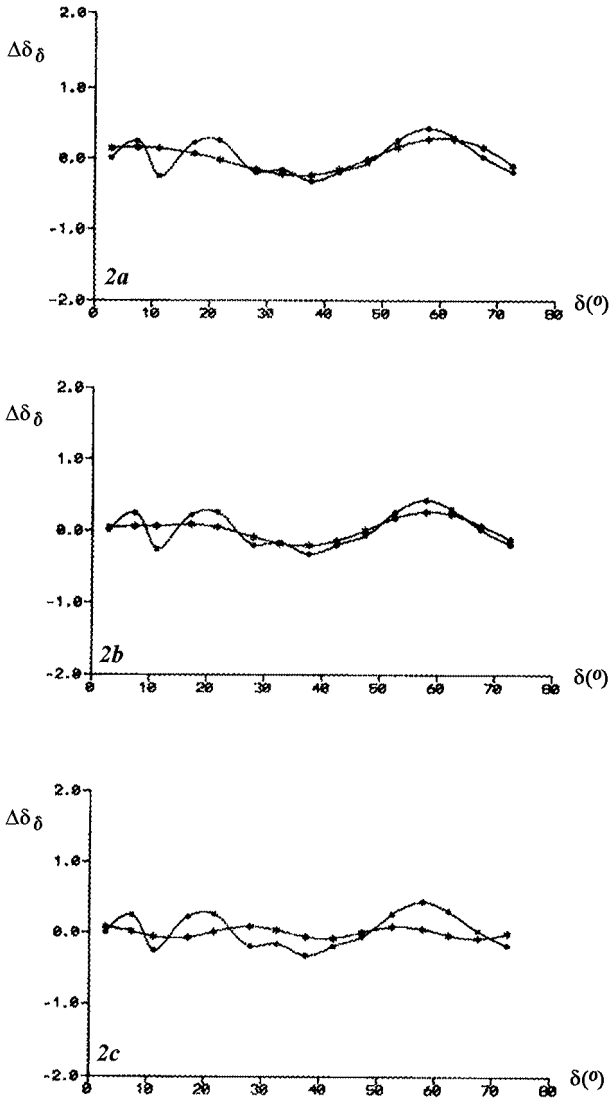


Fig. 2. *Smoothing the differences $\Delta\delta_\delta$ between the Belgrade and Moscow catalogues (pointed curve): a) WRV, b) SPL i c) ETE.*

The methods of smoothing have been applied to the differences averaged according to zone. First the differences positions in right ascensionsa Δ_α and declination Δ_δ have been calculated. Next these differences were reduced to the equator and averaged according to zones (for right ascension the zones extend 1^h, wereas the declination zone are varying).

The results obtained are presented by graphs in Figs. 1 - 10. The graphs marked by a) the WRV metod, in those marked by b) the SPL and in those marked by c) the EPE method has been applied.

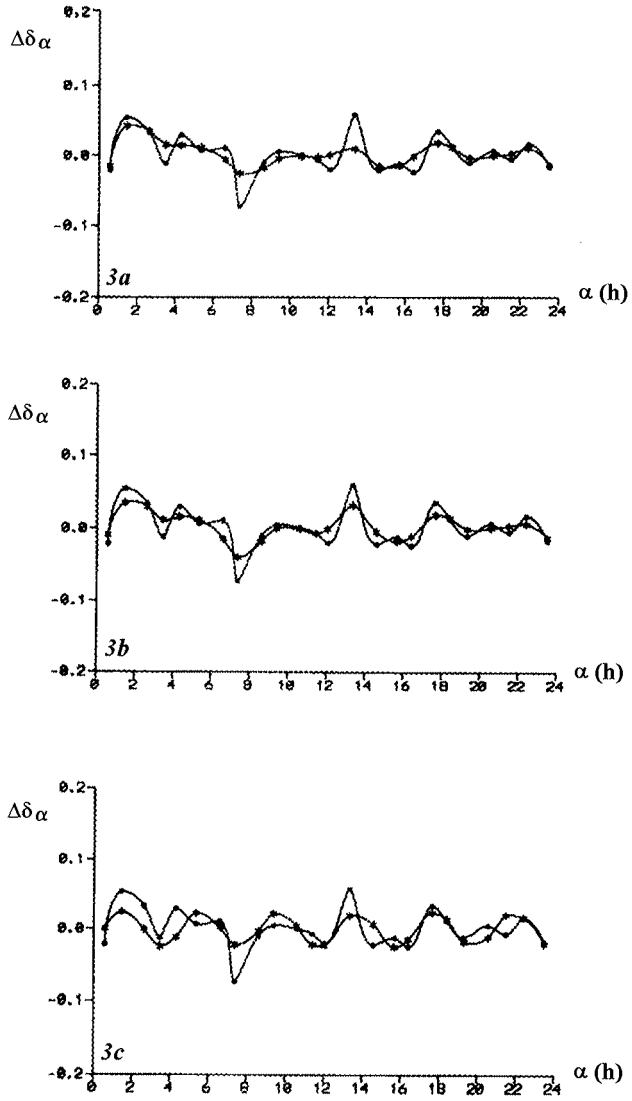


Fig. 3. *Smoothing the differences $\Delta\alpha_\alpha$ between the Belgrade and Kharkov catalogues (pointed curve): a) WRV, b) SPL i c) ETE.*

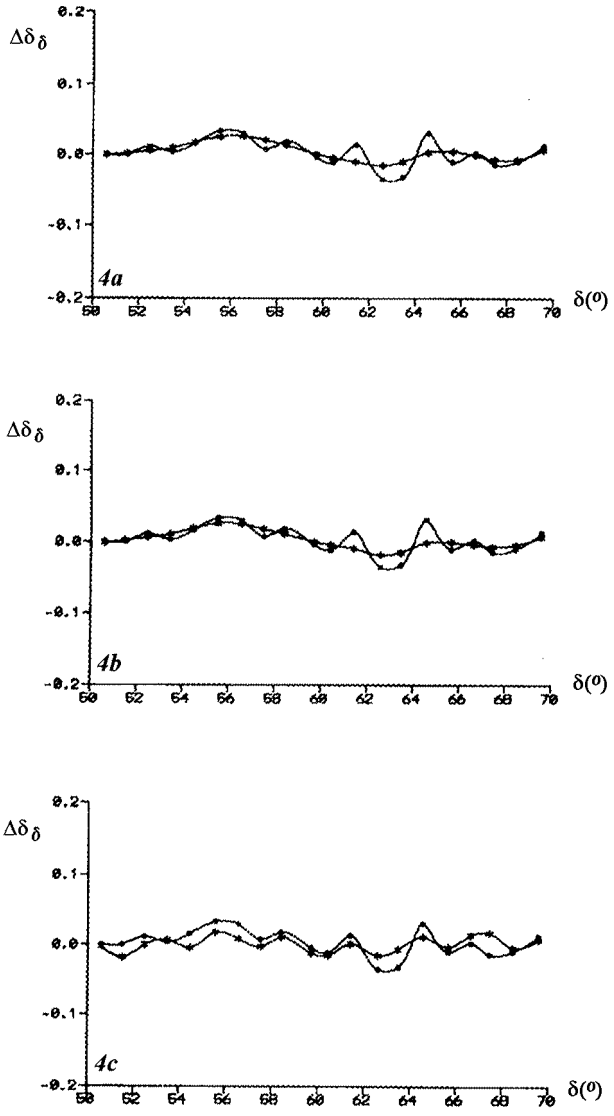


Fig. 4. *Smoothing the differences $\Delta\alpha_\delta$ between the Belgrade and Kharkov catalogues (pointed curve): a) WRV, b) SPL i c) ETE.*

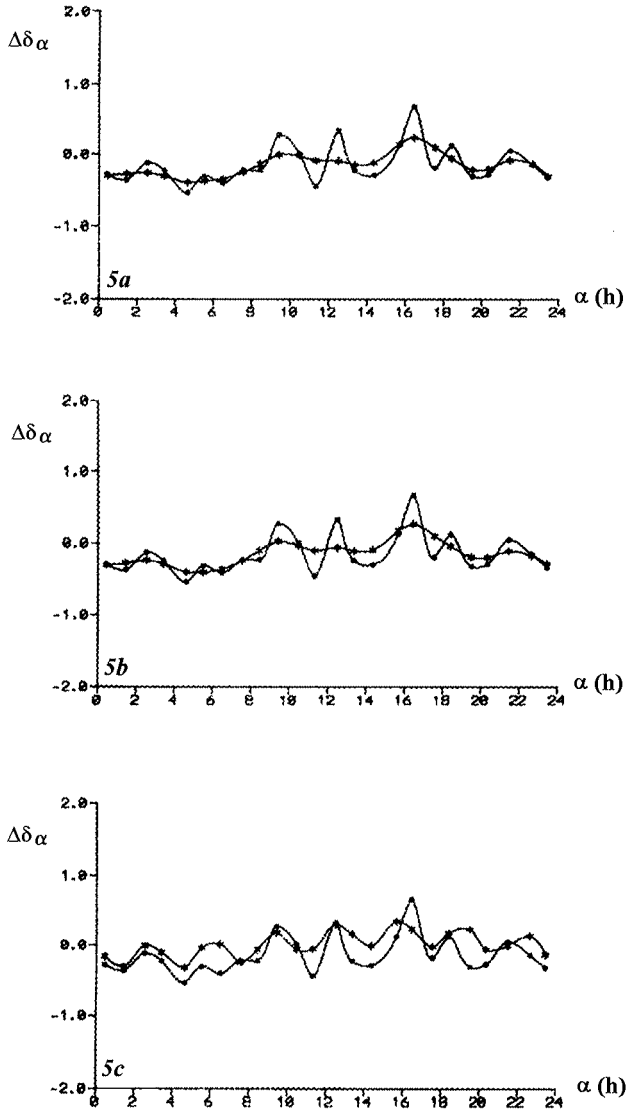


Fig. 5. *Smoothing the differences $\Delta\delta_\alpha$ between the Belgrade and Odessa catalogues (pointed curve): a) WRV, b) SPL i c) ETE.*

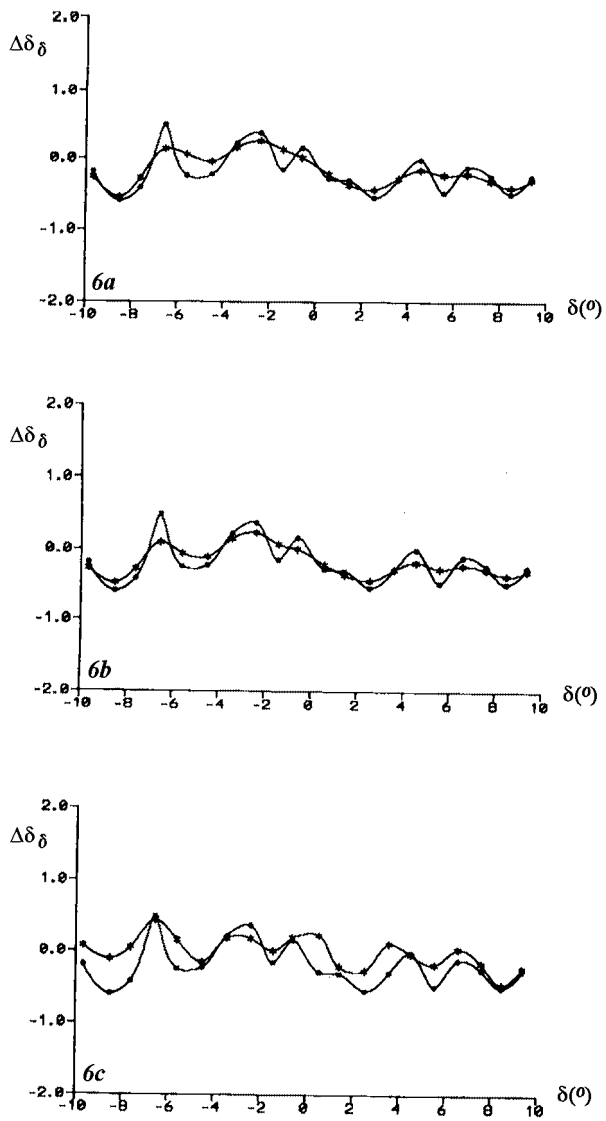
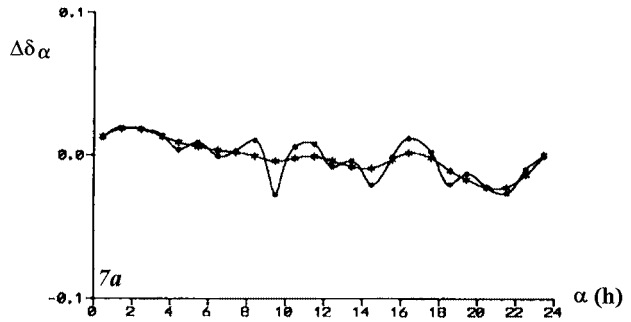
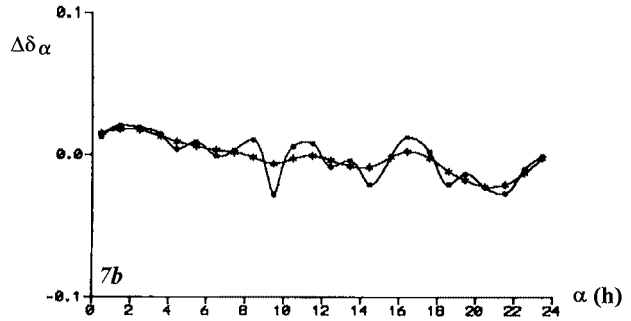


Fig. 6. *Smoothing the differences $\Delta\delta_\delta$ between the Belgrade and Odessa catalogue (pointed curve): a) WRV, b) SPL i c) ETE.*





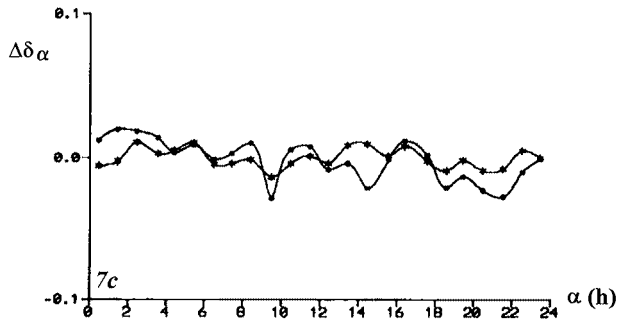
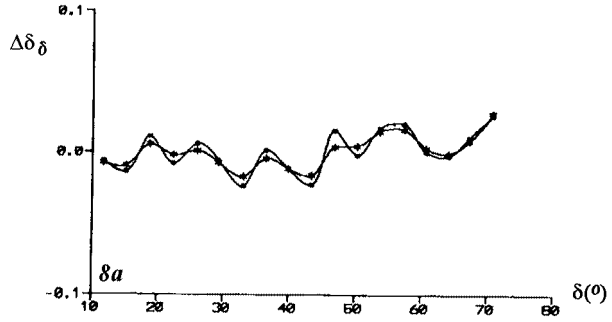
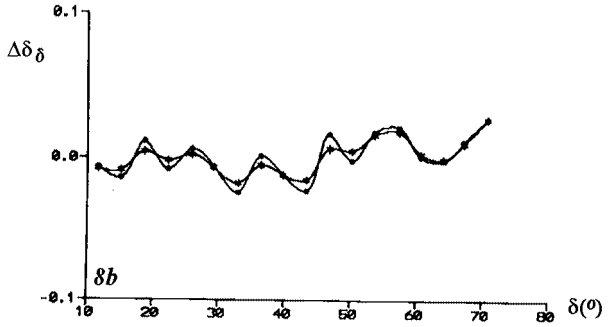


Fig. 7. *Smoothing the differences $\Delta\alpha_\alpha$ between the Belgrade and Kiev catalogues (pointed curve): a) WRV, b) SPL i c) ETE.*





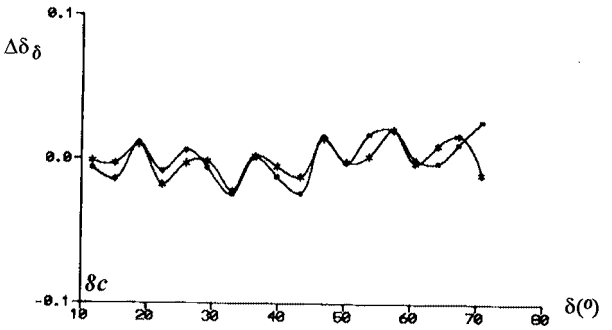


Fig. 8. *Smoothing the differences $\Delta\alpha_\delta$ between the Belgrade and Kiev catalogues (pointed curve): a) WRV, b) SPL i c) ETE.*

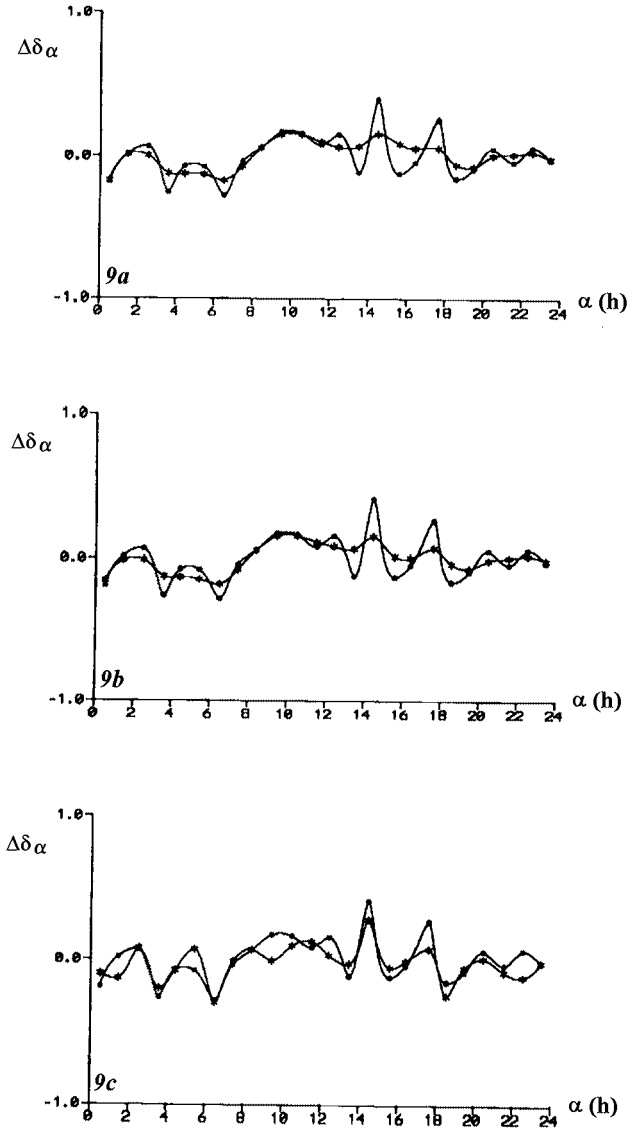


Fig. 9. *Smoothing the differences $\Delta\delta_\alpha$ between the Belgrade and Kiev catalogues (pointed curve): a) WRV, b) SPL i c) ETE.*

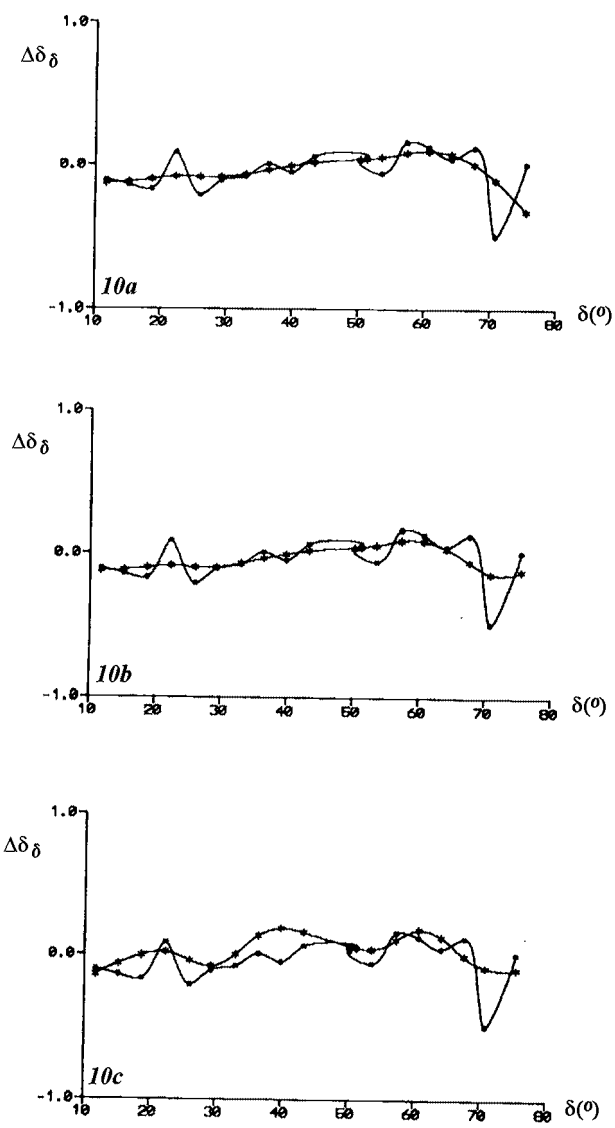


Fig. 10. *Smoothing the differences $\Delta\delta_\delta$ between the Belgrade and Kiev catalogues (pointed curve): a) WRV, b) SPL i c) ETE.*

3. DISCUSION

The smoothing according to WRV and SPL metods has been pushed up to the accidental errors level of the catalogue differences. The smoothing according to the ETE method went until the lowest mean square error.

The smoothing curves resulting from the WRV and SPL metods show essentially the same run while those obtained by the ETE method have somewhat different run. The mean square errors of a single observation ($\sigma_\alpha \cos\delta$ and σ_δ) of the observational catalogues and the mean square errors of a single difference, ($\sigma'_\alpha \cos\delta$ and σ'_δ) are listed in Table 2.

In Table 3. are listed mean errors ($\sigma_{\Delta\alpha_\alpha}$, $\sigma_{\Delta\alpha_\delta}$, $\sigma_{\Delta\delta_\alpha}$, $\sigma_{\Delta\delta_\delta}$) calculated from the deviations of the raw from the smoothed values for all of the three methods.

Table 2. Mean square errors of a single observation ($\sigma_\alpha \cos\delta$ and σ_δ) and of a single difference ($\sigma'_\alpha \cos\delta$ and σ'_δ).

ERRORS	$\sigma_\alpha \cos\delta$	σ_δ	$\sigma'_\alpha \cos\delta = \sqrt{(\pm 0.^s026)^2 + (\sigma_\alpha \cos\delta)^2}$	$\sigma'_\delta = \sqrt{(\pm 0.''34)^2 + (\sigma_\delta)^2}$
BELGRADE	$\pm 0.^s026$	$\pm 0.''34$	–	–
KIEV	$\pm 0.^s027$	$\pm 0.''46$	$\pm 0.^s037$	$\pm 0.''57$
MOSCOW	–	$\pm 0.''30$	–	$\pm 0.''45$
ODESSA	–	$\pm 0.''38$	$\pm 0.^s037$	$\pm 0.''51$
KHARKOV	$\pm 0.^s026$	–	–	–

Table 3. Mean errors ($\sigma_{\Delta\alpha_\alpha}$, $\sigma_{\Delta\alpha_\delta}$, $\sigma_{\Delta\delta_\alpha}$, $\sigma_{\Delta\delta_\delta}$) of the deviations of the raw from the smoothed values.

METHOD	σ	KIEV	MOSCOW	ODESSA	KHARCOV
WRV	$\sigma_{\Delta\alpha_\alpha}$	$0.^s0053210$	–	–	$0.^s0182019$
	$\sigma_{\Delta\alpha_\delta}$	$0.^s0077305$	–	–	0.0124159
	$\sigma_{\Delta\delta_\alpha}$	$0.''1067145$	$0''.1375116$	$0.''1907477$	–
	$\sigma_{\Delta\delta_\delta}$	$0.''1403420$	0.1610936	0.1650484	–
SPL	$\sigma_{\Delta\alpha_\alpha}$	$0.^s0050977$	–	–	0.0150690
	$\sigma_{\Delta\alpha_\delta}$	$0.^s0076067$	–	–	0.0121208
	$\sigma_{\Delta\delta_\alpha}$	$0.''1014614$	0.1355593	0.1858144	–
	$\sigma_{\Delta\delta_\delta}$	$0.''1177891$	0.1424577	0.1549284	–
ETE	$\sigma_{\Delta\alpha_\alpha}$	$0.^s0043475$	–	–	0.0118049
	$\sigma_{\Delta\alpha_\delta}$	$0.^s0043045$	–	–	0.0114094
	$\sigma_{\Delta\delta_\alpha}$	$0.''0939087$	0.1262104	0.1672426	–
	$\sigma_{\Delta\delta_\delta}$	$0.''0917786$	0.1391576	0.1792947	–

The mean errors of the differences of the Belgrade and Kiev catalogues are almost identical for the WRV and SPL methods, whereas those for the ETE methods are by a few thousandths of the time second and a few hundredths of the arc second respectively, are smaller. The same results are obtained for the differences of the Belgrade and the Moscow, Kharkov and Odessa catalogues, except for the differences of the Belgrade and Odessa catalogues concerning the mean error $\sigma_{\Delta\delta_\delta}$ resulting from the ETE method.

4. CONCLUSION

Herefore the differences in the star positions as given in the catalogues have in most cases been treated according to the empirical methods. Now we have at our disposal several analytical methods which can be applied successfully in comparing the catalogues. The ETE method has for the first time been applied to this kind of data, yielding as indicated in the foregoing paragraph, satisfactory results. To be more precise the results adduced in Table 3. suggest this method as reliable and even somewhat more efficacious than the usual WRV and SPL methods.

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ПРИМЕНА МЕТОДА ИЗРАВНАЊА НА РАЗЛИКЕ ПОЛОЖАЈА ЗВЕЗДА У ПОСМАТРАЧКИМ КАТАЛОЗИМА

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Оригинални научни рад

Три разне методе, Whittaker - Robinson - Vondrak (WRV), кубни сплајн (SPL) и Развој у елементарне тригонометријске и експоненцијалне функције (ETE) су примењене на разлике положаја звезда пет посматрачких каталога у циљу елиминисања случајних грешака. Београдски, Кијевски, Московски, Одески и Харковски каталози програма двојних звезда (DS) су коришћени. Метода ETE се појављује као поуздана и чак нешто ефикаснија од уобичајених WRV и SPL метода.