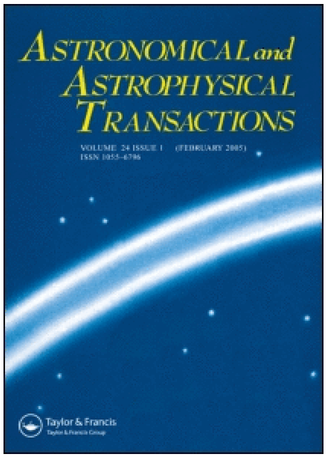

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THE INTERSEASONAL TREND IN PHOTOGRAPHIC DOUBLE STAR OBSERVATIONS

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Photographic observations obtained in Pulkovo and USNO for four visual double stars (ADS 48, 7251, 11632, 12815) have been investigated. Analysis of (O–C) residuals relative to the orbital motion shows one year periods in both series due to systematic seasonal variations in the conditions of observations. The value of the interseasonal trend (systematic residuals of coordinates) reaches $0.015''$ in X and $0.030''$ in Y for Pulkovo and $0.007''$ in X and $0.015''$ in Y for USNO. These values are almost of the same range as the accidental errors of observations, but they may be comparable with amplitudes of oscillations caused by a probable invisible satellite and thus they should be taken into account. The relative motions obtained from both series are in close agreement with each other for all stars.

KEY WORDS Double stars, invisible satellites

1 INTRODUCTION

At Pulkovo, a search for invisible satellites on the basis of photographic observations with the 26-inch refractor is an essential part of visual double star investigations. If the expected period of the invisible satellite is long enough, we use the seasonal mean deviations (O–C) relative to the orbital motion of the star, but if the expected period is shorter (2–5 years), it is naturally better to use individual observations or means for a shorter time interval, for example, 0.1 year. In the process of our research we discovered 1 year period in (O–C) values for Pulkovo and USNO observations. As this period is characteristic of a number of series of observations of different stars and is correlated with Earth's rotation period, we consider this to be interseasonal trend repeating every year.

The investigation was carried out for four stars with long-time series of observations in Pulkovo and USNO: ADS 48, 7251, 11632, 12815 (16 Cygni). The Pulkovo data were taken from our catalogue (Kisselev *et al.*, 1988), the last version of which was sent to the Center of astronomical data in Strasburg in 1993. The USNO data were taken from USNO publications (Josties *et al.*, 1969, 1972, 1978; Josties

Table 1. Data for stars

ADS	α *1950.0* δ		SP_A	SP_B	m_A	m_B	π_t	ρ	θ
48	$00^h03.0^m$	$+45°32'$	K6V	MOV	8.9	8.9	0.094″	6″	172°
7251	09 11.0	+52 54	MOV	MOV	7.4	7.4	0.166	18	86
11632	18 42.2	+59 33	M4V	M5V	8.2	8.7	0.284	14	166
12815	19 40.5	+50 24	GOV	GOV	5.1	5.3	0.047	39	133

and Harrington, 1984), but we used only data for plates measured with Strand Automatic Measuring machine (SAMM) to have a uniform series. The Pulkovo observations of ADS 48 were measured by the author with the "Parsec" (Sergeev and Shornikov, 1984) automatic measuring machine, the other stars were measured visually with the "Ascorecord" Zeiss plate measuring machine by N. A. Shakht and L. G. Romanenko. The method of reductions was the same in both cases; it is described in Kisselev *et al.*, 1988.

2 DISCUSSION OF THE RESULTS

The general data for each star - coordinates (α, δ), spectral types of components $(SP_A,\ SP_B)$, magnitudes $(m_A,\ m_B)$, trigonometric parallax (π_t), mean values of relative coordinates (ρ, θ) - are given in Table 1.

To reduce the effect of accidental errors, we calculated mean positions (normal places) for adjacent plates with moments of observations differing less than by 0.1 year. These smoothed series constituted initial data for our investigation. The apparent relative orbital motion of a star at the moment t_0 is described by the following equations:

$$\left.\begin{aligned} x_i &= x_0 + \dot{x}_0(t_i - t_0) + \ddot{x}_0((t_i - t_0)^2)/2 \\ y_i &= y_0 + \dot{y}_0(t_i - t_0) + \ddot{y}_0((t_i - t_0)^2)/2 \end{aligned}\right\} \tag{1}$$

where $t_0 = (t_n - t_1)/2$, (t_i, x_i, y_i) are, respectively, the moment and the relative position for the corresponding normal place.

Solving (1) by means of the least square method, we receive the motion parameters $x_0, \dot{x}_0, \ddot{x}_0, y_0, \dot{y}_0, \ddot{y}_0$ and deviations relative to the orbital motion of the star.

The data on the Pulkovo (P) and Washington (W) series of observations are presented in Table 2, where Δt is time period of observations; N, number of plates in the series; n, number of normal places; n', mean number of plates corresponding to one normal place; σ_{1x} and σ_{1y}, dispersions in coordinates x and y as the result of reduction according to formulae (1).

The interseasonal trend - a dependence between the mean value of deviation and phase (fraction of the year, 0.0 and 1.0 correspond to January 0) - is presented graphically in Figures 1–4. The errors of data points are indicated where possible.

Table 2. Characteristics of observational series

ADS		Δt	N	n	n'	σ_{1x}	σ_{1y}
48	P	1968–89	99	34	4	0.005″	0.008″
	W	66–73, 81	67	22	4	4	5
7251	P	62–83	122	38	4	11	12
	W	66–88	167	35	8	3	5
11632	P	68–89	138	41	5	20	33
	W	63–81	168	54	5	5	6
12815	P	69–93	86	24	5	12	13
	W	67–81	318	50	10	7	7

It should be noted that observational conditions for ADS 11632 in Pulkovo are unfavorable. Owing to "white nights", we cannot observe this star in summer. Therefore we observe it in August–September when the hour angle is 1–2 hours. It is the first star in the evening program of observations, when weather changes from a warm day to a cool night. This introduces errors into observations which we see in the graphs.

It is apparent that interseasonal trend exists for all the stars studied. For this reason, the systematic residuals of coordinates reach 0.015″ in X and 0.030″ in Y for Pulkovo and 0.007″ in X and 0.015″ in Y for USNO. (Usually we obtain approximately the same values for the amplitude due to an invisible satellite.)

The interseasonal trend depends on the distance between components and their orientation in space. For the close pair ADS 48 with orientation in Y ($\rho = 6''$, $\theta = 172°$), the effect is much less then for wide pairs ADS 11632 ($\rho = 14'', \theta = 166°$) and ADS 12815 ($\rho = 39'', \theta = 133°$), but for a wide pair ADS 7251 with orientation in X ($\rho = 18'', \theta = 86°$) there is no interseasonal trend in Y. Thus we can conclude that the main reason for the interseasonal trend is the change of anomalous refraction.

COMPARISON OF PULKOVO AND USNO SYSTEMS

The apparent motion parameters ρ, θ, and $\mu = \sqrt{\dot{\rho}^2 + (\rho\dot{\theta})^2}$ for a common moment t_0 were obtained on the basis of the Pulkovo and USNO series of observations separately. We used only the common part of the series, when there were observations by both observatories. The calculations have been carried out according to a formula similar to (1) in two modes:

1) using seasonal mean positions, when the interseasonal trend is smoothed;

2) using positions of each plate's reduction.

We use here the coordinate system (ρ, θ) for separating system residuals $\Delta\tau = \rho\Delta\theta$ which are connected with orientation treatment and $\Delta\rho$ connected with device-measurement errors, but free from orientation errors.

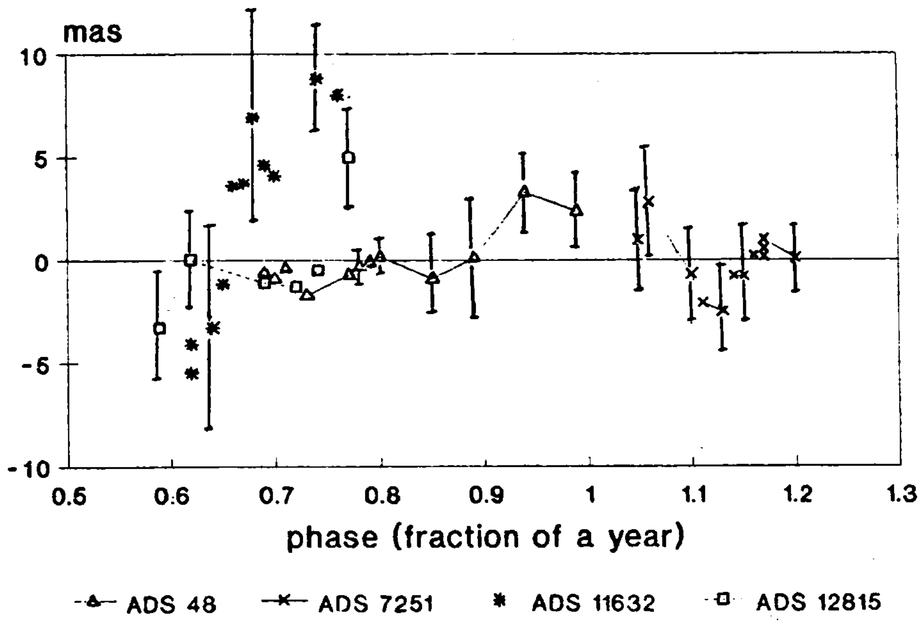

Figure 1 $(O-C)_x$ for Pulkovo series.

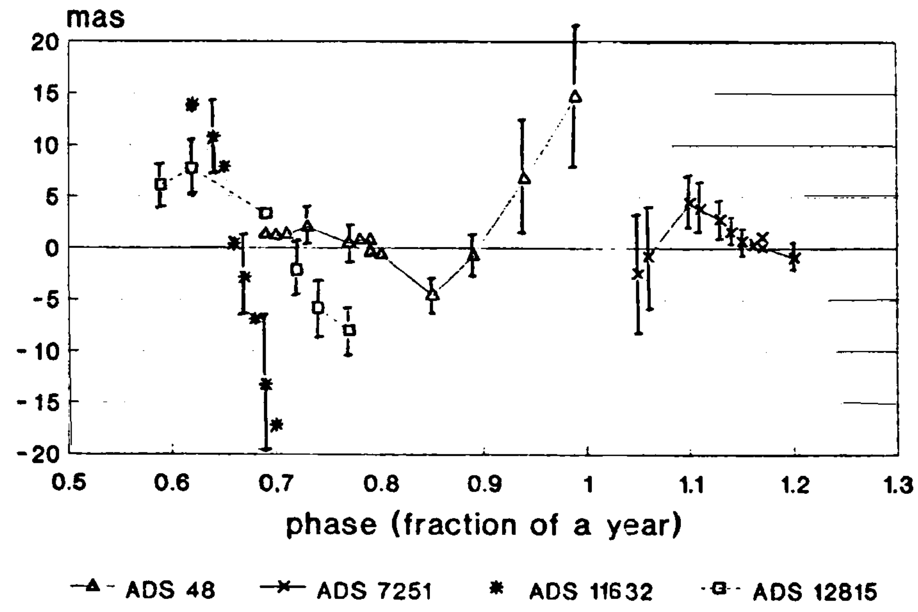

Figure 2 $(O-C)_y$ for Pulkovo series.

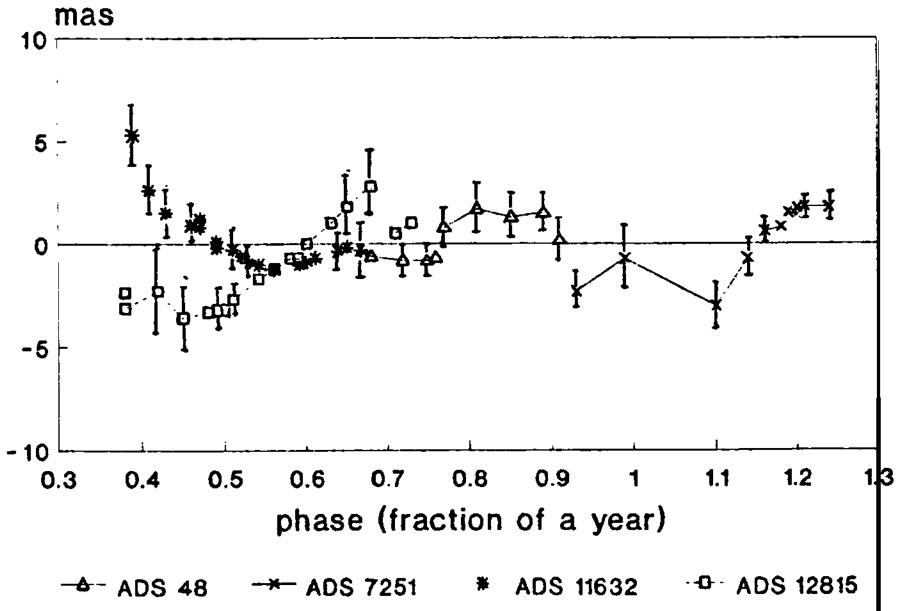

Figure 3 $(O-C)_x$ for USNO series.

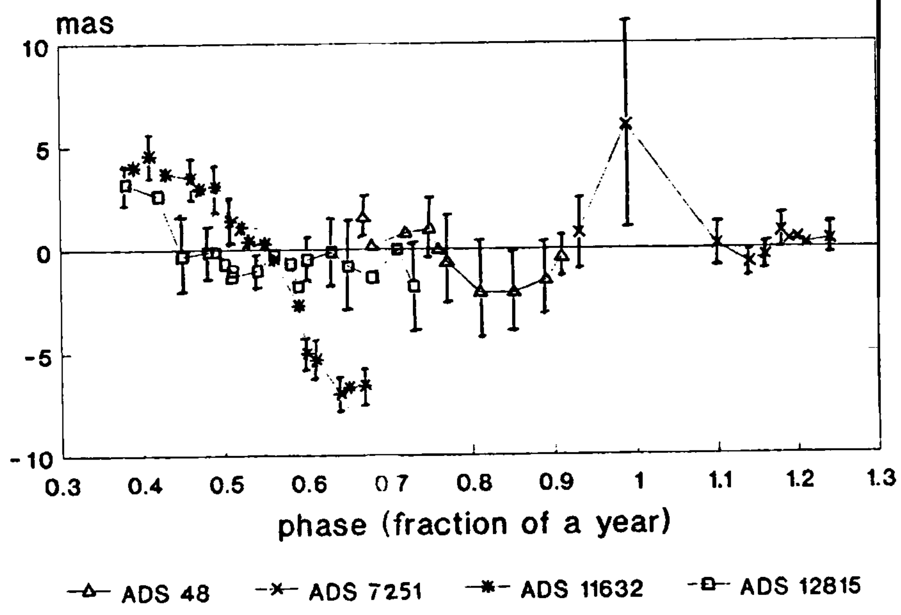

Figure 4 $(O-C)_y$ for USNO series.

Table 3. System residuals between USNO and Pulkovo at the moment t_0

		Var. 1: seasonal means				*Var. 2: plates*			
ADS	t_0	$\Delta\rho$ *[arcsec]*	$\Delta\tau$	μ *[mas]*	$\Delta\mu$	$\Delta\rho$ *[arcsec]*	$\Delta\tau$	μ *[mas]*	$\Delta\mu$
48	1972.3	-0.002	+0.005	46.4	-0.3	-0.002	+0.008	46.8	-0.6
		±3	±3	±8	±1.2	±3	±2	±5	±9
7251	1974.1	-0.016	-0.025	93.5	+0.1	-0.015	-0.027	94.0	-1.6
		4	4	7	8	3	4	6	7
11632	1973.6	-0.058	-0.018	97.8	-0.8	-0.062	-0.023	99.4	-2.5
		11	4	1.5	1.6	7	4	1.2	1.3
12815	1975.6	-0.002	-0.008	10.7	+2.9	-0.012	-0.020	11.8	+1.6
		6	8	2.4	2.4	4	4	9	9

The values of the relative motion μ obtained for Pulkovo series and the residuals between USNO and Pulkovo (W–P) parameters $\Delta\rho, \Delta\tau$, and $\Delta\mu$ are given in Table 3.

It is apparent that the automatic measurements for ADS 48 which were made by different measuring machines in Pulkovo and USNO are in closer agreement with each other than manual and automatic measurements for other stars.

It is also apparent that there is a systematic residual in coordinates but the relative velocity μ is the same for the both independent observatories, especially for the seasonal mean position mode. This fact is very important for orbit determinations made by the method of apparent motion parameters which we usually apply in Pulkovo (Kisselev and Kiyaeva, 1980).

3 CONCLUSIONS

1. There exists an interseasonal trend in the relative positions of visual double star observations. It is necessary to take into account the fact that the value of the interseasonal trend is of the same order as the value we can expect for the amplitude of invisible satellites.
2. The Pulkovo series exceed the corresponding errors of USNO series. This is explained by the following:
   (1) automatic measurements are more precise and uniform than manual measurements;
   (2) weather conditions in Pulkovo are worse than in Washington, especially in autumn; in turn, this is one of the reasons why the values of the interseasonal trend in Pulkovo are higher than in USNO;
   (3) the number of plates in the series is less in Pulkovo than in USNO, the number of images on the plates is also much less in Pulkovo (≈ 15) than in USNO (≈ 60).

3. Pulkovo and USNO series are uniform and suitable for detailed investigations of visual double stars orbital motions.

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