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CHARACTERISTICS OF PROPER MOTIONS IN THE PRELIMINARY COMPILED DOUBLE STAR CATALOGUE

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SUMMARY: The author presents the analysis of the proper motions of A-components of the double stars from the Preliminary Compiled Catalogue of DS-Programme Star Positions. A few statistical criteria are applied to the proper motions of the stars mentioned above aimed at identifying orbital motions of the A-components around the mass centres. Two statistical relations known from stellar astronomy are applied in order to determine the parallaxes. The mass-centre proper motions for the catalogue double stars are calculated, as well.

1. INTRODUCTION

Among stars interesting to the astronomical research are also double stars (DS), relatively close to us, thus having high proper motions. The knowledge of these proper motions is very important to galactic astronomy, especially when the fine galactic structure in the solar neighbourhood is studied. The importance of knowing the accurate positions and proper motions of double stars is seen from the fact that the double (and multiple) stars are objects of special importance in the programme "HIPPARCOS".

By using the star positions determined in 1930 by Courvoisier (1951) and those from the Preliminary Compiled Catalogue of DS-Programme Star Positions (Cvetković, 1992) the proper motions of 421 stars have been determined. A special attention has been devoted to a statistical examination aimed at establishing if orbital motions around the mass centre of the binaries can be found.

2. A STATISTICAL CRITERION OF IDENTIFICATION OF ORBITAL MOTIONS

The components of binaries possess the orbital motion around their mass centres, hence their proper motion on the sky is "wavy" and only their mass centres move along the arc of a great circle like the single stars. Therefore, the proper motions of A-components of the double stars obtained by the author are the total annual changes of their positions composed of the orbital motion around the mass centre and the motion of the mass centre itself.

As the parallaxes of the components of a binary are practically equal and the same is true for the effect of interstellar absorption, $\Delta M = \Delta m$ is valid for any photometric system. On the other hand, as well-known, the theoretical relation "mass-luminosity" for the stars of approximately equal chemical composition assigns a higher luminosity to a higher mass.

The magnitude difference $\Delta m=0.0$ indicates approximately equal masses of a binary star components, i.e. their approximately equal orbital motion. As Δm increases, the brighter A-component, in view that it is more massive, is closer to the system mass centre and, therefore, its orbital motion is "smaller" than that of the other component. In other words the orbital motion of the observed binary-system component is the most significant for $\Delta m=0$ and it decreases when Δm increases. Naturally, this conclusion is correct if Δm is influenced by the mass ratio only, i.e. it is valid for an approximately equal chemical composition and evolutionary status of the components.

In the present double-star sample ($\Delta m=0.0$-4.0) the obtained proper motions of the A-components are averaged statistically by dividing the stars into four groups according to their Δm. The results are presented in Table 1 where Δm is the magnitude difference of the components; N is the number of stars within a group; s_1, s_2, s_3 are the root-mean-square errors for μ, μ_α and μ_δ, respectively. (In case of μ_α and μ_δ the moduli are presented).

It is clearly seen (Table 1) that the mean values of μ, μ_α and μ_δ within the groups, as well as the corresponding rms errors, decrease with the increase in Δm. In order to verify if the mean proper motion changes are affected by the decrease in the number of stars N within a group the dispersions σ_i^2 of the dispersions s_i^2 are calculated according to the formula

$$\sigma_i = (2/(N-1))^{1/2} s_i^2 \qquad i = 1,2,3 \ .$$

From $\sigma_i \approx$const (Table 2) it is possible to conclude that the decrease in N is not the cause of the decrease in the proper motions with Δm increasing, but that this fact is rather an indication of the orbital-motion influence.

3. AN APPLICATION OF TWO STATISTICAL RELATIONS OF STELLAR ASTRONOMY

The following two statistical relations are applied in order to estimate the proper motions of the mass centres of the catalogue double stars and consequently the orbital motions of the observed components themselves.

The first relation is due to Binnendijk (1943)

$$\log \pi(m) = log\pi(12.0) - 0.115(m - 12.0) \qquad (1)$$

and the second one is due to Kapteyn and van Rhijn (see e.g. Куликовский, 1985)

$$log\pi(m,\mu) = -0.690 - 0.0713m + 0.645 log\mu \ . \qquad (2)$$

Both statistical relations hold for the single stars. Their direct application to binaries is incorrect. If there is any indication that the more massive system component is practically its mass center, its $\mu(=\mu_c)$ will be free of orbital motion and relation (2) for that component will give the system parallax.

Table 1. Mean Values of Proper Motions μ and of Components μ_α and μ_δ within the Groups

Δm	N	μ	s_1	μ_α	s_2	μ_δ	s_3
0 - 1	205	0''.065	±0''.068	0''.043	±0''.056	0''.039	±0''.048
1 - 2	138	0''.042	±0''.052	0''.025	±0''.040	0''.027	±0''.038
2 - 3	61	0''.037	±0''.048	0''.023	±0''.037	0''.024	±0''.034
3 - 4	14	0''.020	±0''.014	0''.012	±0''.009	0''.014	±0''.015

Table 2. The Values σ_i within the Groups

Δm	σ_1	σ_2	σ_3
0 - 1	0.0004	0.0003	0.0002
1 - 2	0.0003	0.0002	0.0002
2 - 3	0.0004	0.0003	0.0002
3 - 4	0.0001	0.0000	0.0001

However, no statistics of this kind is made, probably because the masses of visual binary components (of the known orbits) are of the same order of magnitude.

For our stars these is no information on the components mass ratio. The only thing to be said is, that in the systems with the highest Δm the smallest influence of orbital motion on the measured μ is expected.

Bearing this in mind for a small sample of double stars (26 only) with known trigonometric parallaxes π_{tr} (1952) one calculates the proper motion of the mass centre μ_c using (2). The diference $\pm\Delta\mu=\mu-\mu_c$ corresponds to the orbital motion of the observed component around the mass centre.

The $\Delta\mu$ values and the corresponding rms errors s_3 averaged within the groups of Δm (Table 3) decrease with Δm increasing - a fact indicating the orbital motion. In addition, the values of $\Delta\mu$ obtained from this small sample are not significantly smaller than those of μ_c .

Here, the following should also be taken into account: for $\mu_c(1)$ and $\mu_c(2)$ determined for the first and second components, respectively, from (2) it follows:

$$log\frac{\mu_c(1)}{\mu_c(2)} = \frac{b}{c}\Delta m \quad .$$

Since $\mu_c(1)=\mu_c(2)$, it follows that Δm=0, namely the smallest discrepancy of $\mu_c(1)/\mu_c(2)$ from the unity is for the lowest Δm. In other words, a "more accurate" μ_c corresponds to the minimum value of Δm, so that the error in determining the μ_c increases (Δm grows) in the direction of decrease in $\Delta\mu$ in Table 3.

For a majority of the double stars from the sample for which π_{tr} is not available the parallaxes are calculated by using (1). They are denoted as π_b . The next step is to calculate μ_c and $\pm\Delta\mu$ (the values given in Table 4). It is clearly seen that the orbital motions $\Delta\mu$ do not decrease with Δm increasing. In any case the orbital motions of the components $\Delta\mu$ are not negligible in comparison with the proper motions of the mass centres μ_c .

Using the parallaxes π_{tr} or π_b in the relation

$$M = m + 5 + 5log\pi \tag{3}$$

we have determined the absolute magnitudes M also making the spectrum - luminosity diagrams for both the stars with the known π_{tr} (Fig.1) and those with the computed π_b (Fig.2).

Our double stars of all spectral types are distributed approximately within the absolute magnitudes M=1 to M=4 (Fig.2), i.e. there is practically no spectral type dependent change in M. This imposes the necessity of checking the reliability of the obtained results. Much more so because the positions of the 26 sample stars with known parallaxes π_{tr} have not been isolated on the H-R diagram. The most serious reserve is due to a small absolute luminosity of the B and A spectral type stars (especially B type).

Formula (1) used for the calculation of π_b has been derived for the stars fainter than m=10.5 . Therefore, it becomes necessary to extrapolate because the stars treated here are brighter ($6 < m < 9$). In addition, it is seen from Binnendijk's paper that the errors of parallax determination increase in the case of brighter stars, which together with the uncomputed absorption in (3), could lead to a fictitious

Table 3. Mean Values of Proper Motions μ, μ_c and $\Delta\mu$ for 26 Double Stars with known π_{tr}.

Δm	N	μ	s_1	μ_c	s_2	$\Delta\mu$	s_3
0 - 1	12	0″.311	±0″.393	0″.205	±0″.215	0″.186	±0″.192
1 - 2	7	0″.100	±0″.098	0″.201	±0″.169	0″.128	±0″.146
2 - 3	6	0″.102	±0″.125	0″.152	±0″.266	0″.094	±0″.136
3 - 4	1	0″.023	-	0″.095	-	0″.072	-

Table 4. Mean Values of Proper Motions μ, μ_c and $\Delta\mu$ for Double Stars with computed parallaxes π_b.

Δm	N	μ	s_1	μ_c	s_2	$\Delta\mu$	s_3
0 - 1	205	0″.065	±0″.068	0″.061	±0″.021	0″.050	±0″.050
1 - 2	138	0″.042	±0″.052	0″.064	±0″.022	0″.049	±0″.037
2 - 3	61	0″.037	±0″.048	0″.073	±0″.024	0″.050	±0″.040
3 - 4	14	0″.020	±0″.014	0″.093	±0″.030	0″.074	±0″.031

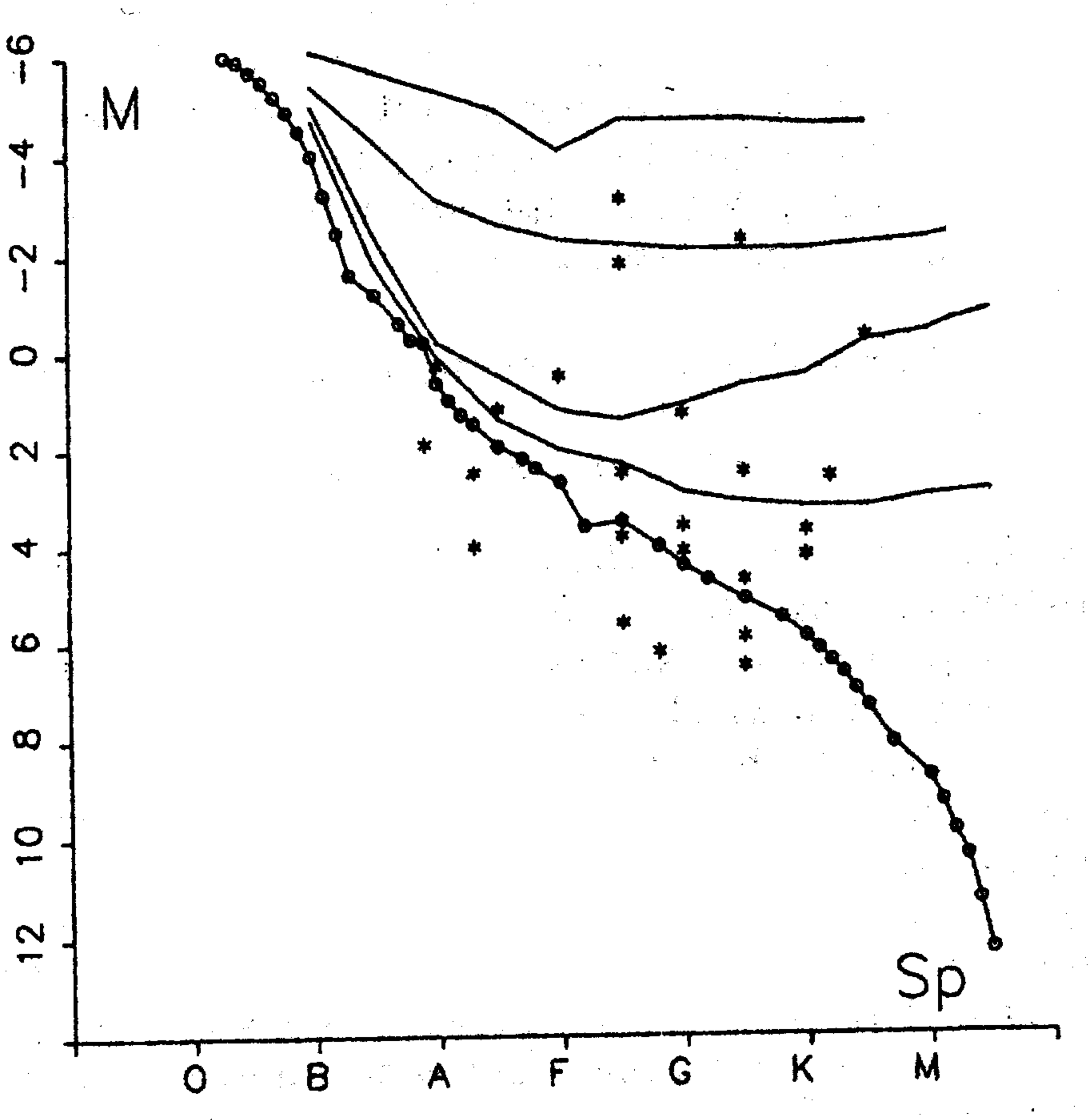

Fig.1. **H-R diagram for 26 double stars with π_{tr} known.**

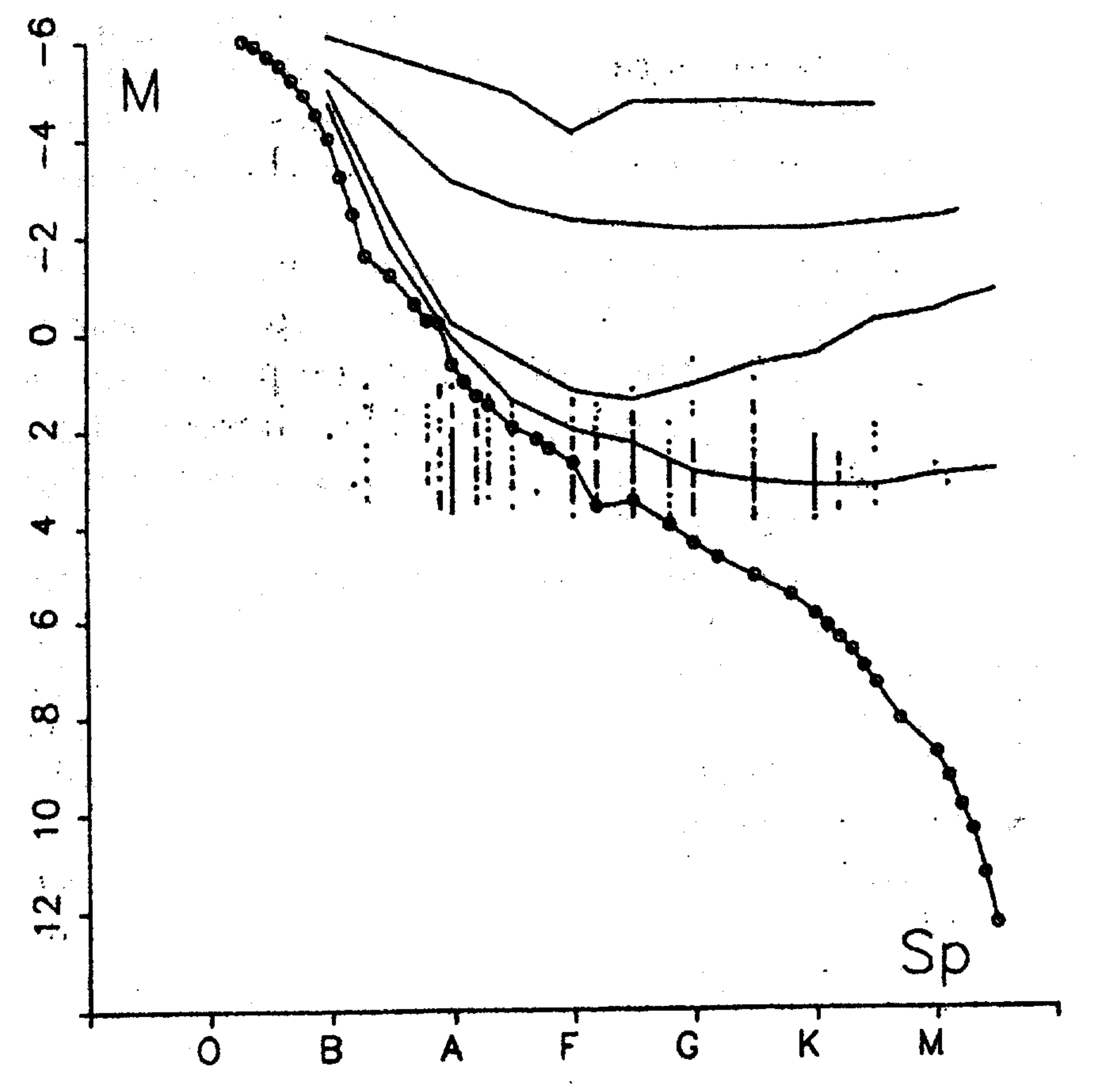

Fig.2. **H-R diagram for double stars with computed parallaxes π_b.**

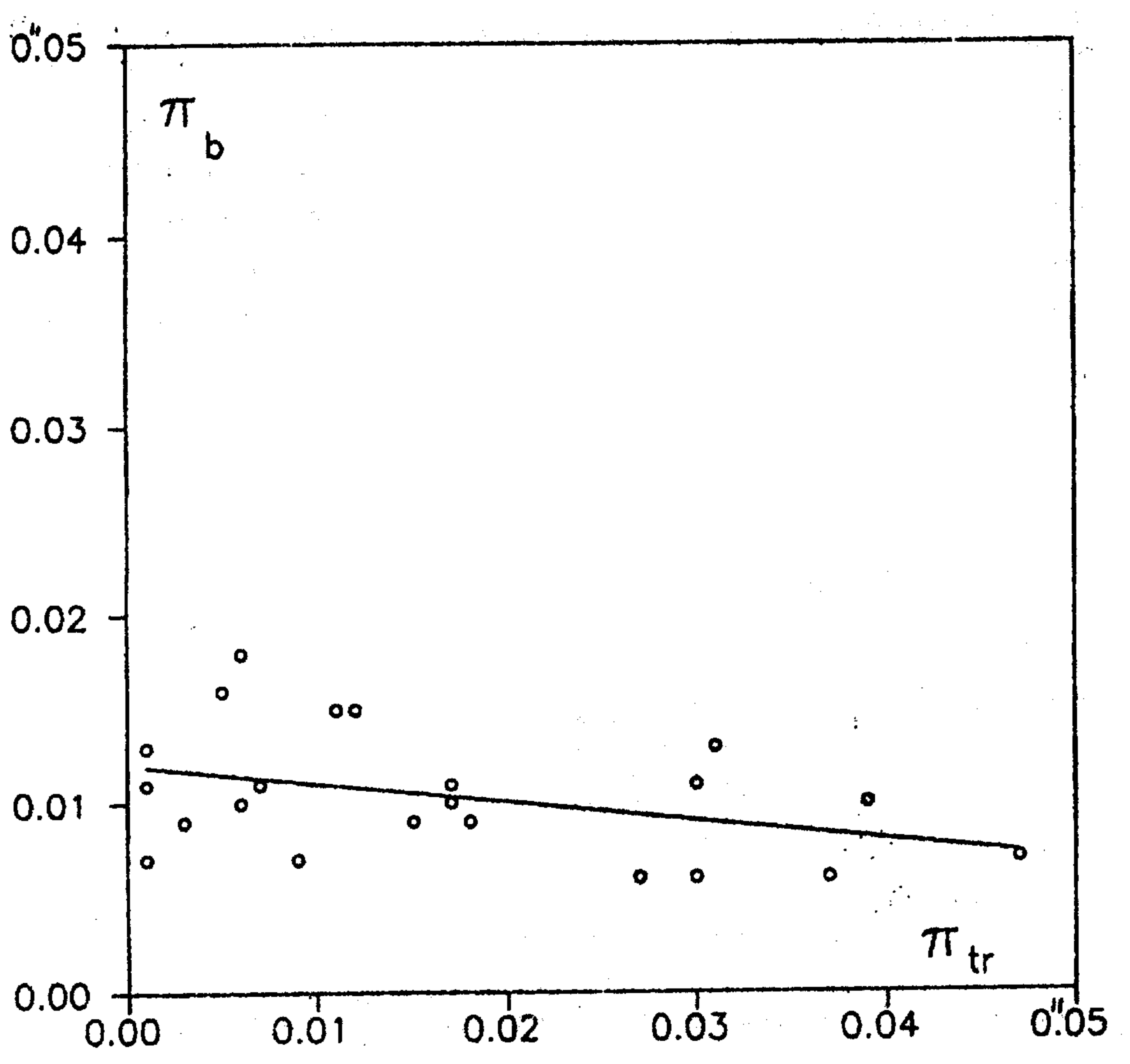

Fig.3. **The dependance $\pi_b(\pi_{tr})$ for the sample of 26 double stars.**

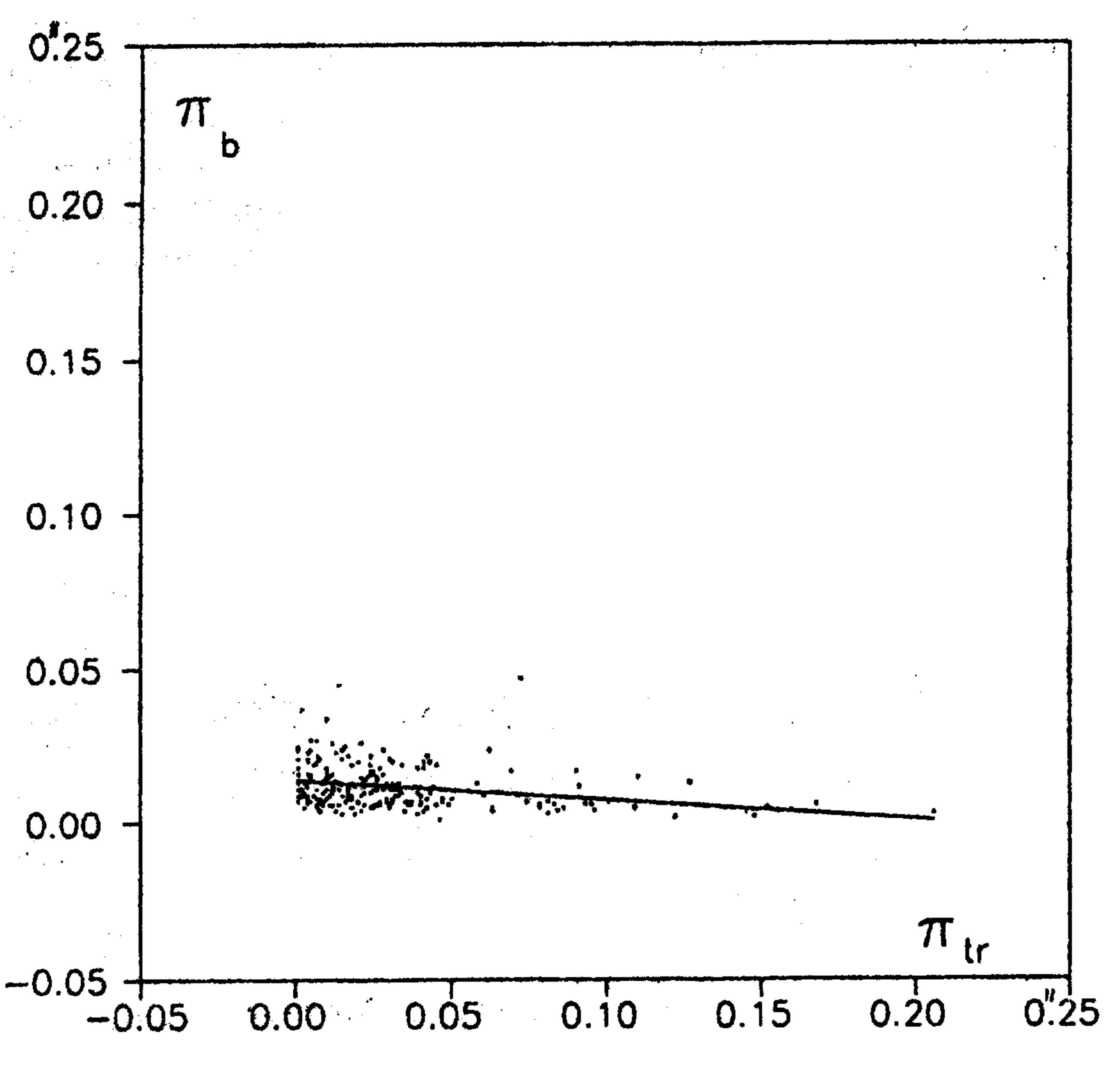

Fig.4. **The dependance $\pi_b(\pi_{tr})$ for the sample of 232 luminous stars.**

distribution of the stars in Fig.2 .

The attempt of correcting π_b for brighter stars through the correlational dependence on π_{tr} yields no results, since in the case of significant changes of π_{tr} there are no significant changes in π_b (see Figs. 3 and 4). Fig.3 gives the dependence $\pi_b(\pi_{tr})$ for 26 double stars; the straight line equation has the form π_b=-0.1013π_{tr}+0.0121. Fig.4 gives the dependence $\pi_b(\pi_{tr})$ for the random sample of 232 luminous stars (without companions), with magnitudes from 3 to 11 of all spectral types; the straight line equation has the form π_b=-0.0659π_{tr}+0.0141 . On account of all these findings one concludes that Binnendijk's relation is not applicable to apparently bright stars and consequently to the present DS sample. In other words, the results from Table 4 and Fig.2 are not realistic.

4. CONCLUSION

From the analysis of the derived proper motions existence of orbital motions for the observed component is clearly seen.

The examination of the proper motions by applying the well-known statistical relations has not yielded any reliable results concerning the amounts of the proper motions of the mass centres because the sample of 26 double stars with π_{tr} known is too small for any statistics and the parallaxes π_b obtained here are not realistic since Binnendijk's relation is not applicable to relatively bright stars.

Obviously, for the proper-motion analyses of the double star components information about the orbital motion is necessary.

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КАРАКТЕРИСТИКЕ СОПСТВЕНИХ КРЕТАЊА У ПРЕЛИМИНАРНОМ ИЗВЕДЕНОМ КАТАЛОГУ ДВОЈНИХ ЗВЕЗДА

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Оригинални научни рад

Аутор представља анализу сопствених кретања А-компонената двојних звезда из Прелиминарног изведеног каталога положаја звезда DS програма. Примењено је неколико статистичких критеријума на сопствена кретања звезда са циљем да се идентификују орбитална кретања А-компонената око центара маса. Примењене су две познате статистичке релације из звездане астрономије због одређивања паралакси. Такође су израчуната сопствена кретања центара маса за двојне звезде каталога.