Serb. Astron. J. № 169 (2004), 59 - 64

UDC 521.328
Professional paper

ORIENTATIONS OF ORBITAL PLANES OF BINARIES

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(Received: October 14, 2004; Accepted: October 21, 2004)

SUMMARY: Orientations of orbital planes of binaries are analysed by using a complete sample of known orbital systems. The use of a so large sample is possible due to the application of a new procedure enabling to include the binaries for which the ascending nodes do not certain. It is concluded that, generally, the distribution of observed orientations of the orbital planes does not differ from simulated random orientations. In both cases the same star positions are retained.

Key words. astrometry – binaries: visual

1. INTRODUCTION

According to the recent literature, there are many binaries with known orbital motion. However, for a majority of them the line-of-sight velocity measurements are not available and, consequently, the true longitude of the ascending node is unknown. This fact appears as an obstacle in the drawing of a qualitative conclusion concerning the distribution of orbital poles. Namely, when the ascending node Ω, apparent inclination i and the coordinates of the system are known, the poles for such an orbit can be found (Eqs. (1)).

$$\alpha_0 = \alpha - \arctan \frac{w}{\sqrt{1-w^2}}$$
$$\delta_0 = \arctan \frac{v}{\sqrt{1-v^2}} \qquad (1)$$

where

$$v = \sin\delta \cos i + \cos\delta \sin i \sin\Omega$$

$$w = \sin i \cos\Omega \cos^{-1}\delta_0.$$

The question of orientations of the orbital planes, a very important one for the solving of the problem of origin of binaries, has been treated by many authors.

Chang (1929), Finsen (1933) and Arend (1950), on the ground of a study of a small number of orbits, conclude that this orientation has most probably a random character. A similar conclusion for the case of eclipsing binaries is reached by Huang and Wade Jr (1966). Bespalov (1961) also concluded that the orbital inclinations in his sample do not show any preferential value.

Batten (1967) examined the orbital-plane orientation for 52 binary systems. According to that author there are wide regions in the northern galactic hemisphere containing a very small number of orbital poles. Therefore it is concluded that it is premature to maintain that the distribution of orbital planes is random.

Lippincott's (1967) examinations are aimed at studying the orbital planes of binaries in connection with their space velocities, whereas the paper of Yavuz (1979) concerns the orbital-plane orientation for spectroscopic binaries. Visual binaries were studied by Dommanget (1973, 1988). His conclusion (1988) is that their orbital planes do not show any tendency to be parallel to the galactic plane.

Popović (1998) analyses the orbital-plane orientation for 78 binaries to find also regions with no orbital poles. Finally, a rather large sample, compri-

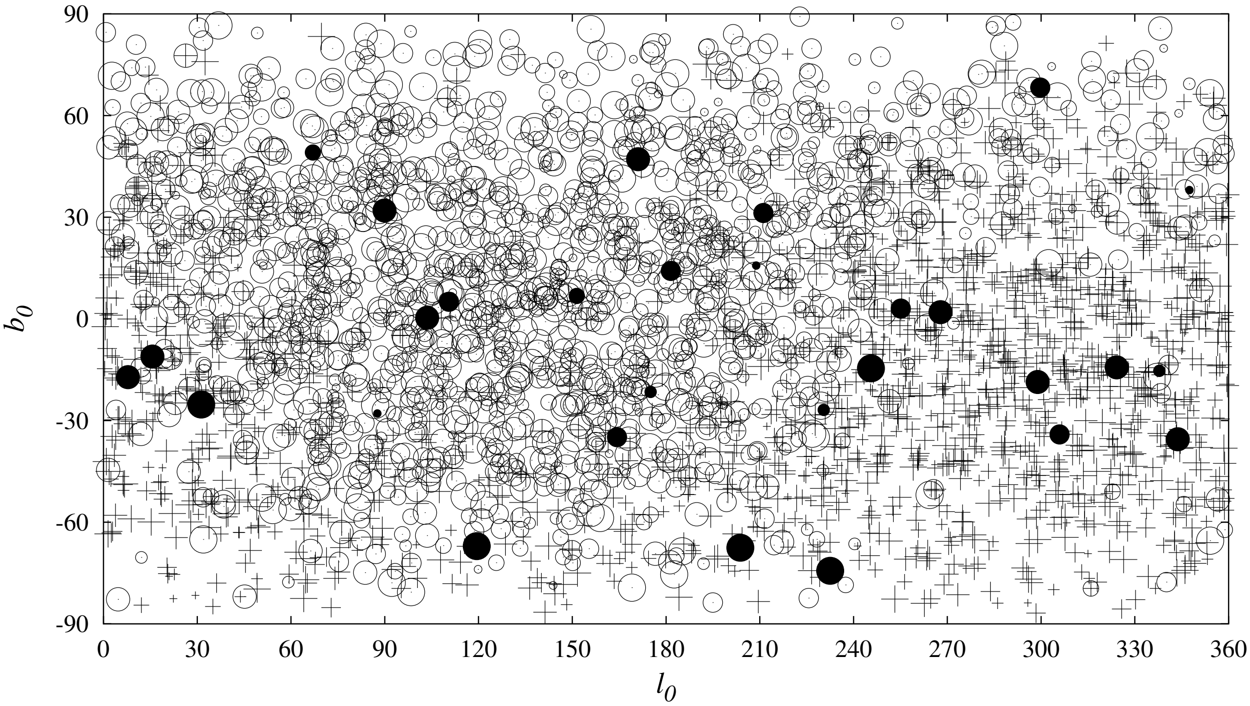

Fig. 1. *The poles for true distribution in galactic coordinates* (l_0,b_0) *with* $\Omega < 180°$ (○) *and corresponding mirror poles* (+). *The designation* (●) *refers to the stars with known ascending node. The size of the sign is inversely proportional to orbit quality – the smallest one corresponds to grade 1, the biggest one to grade* > 5.

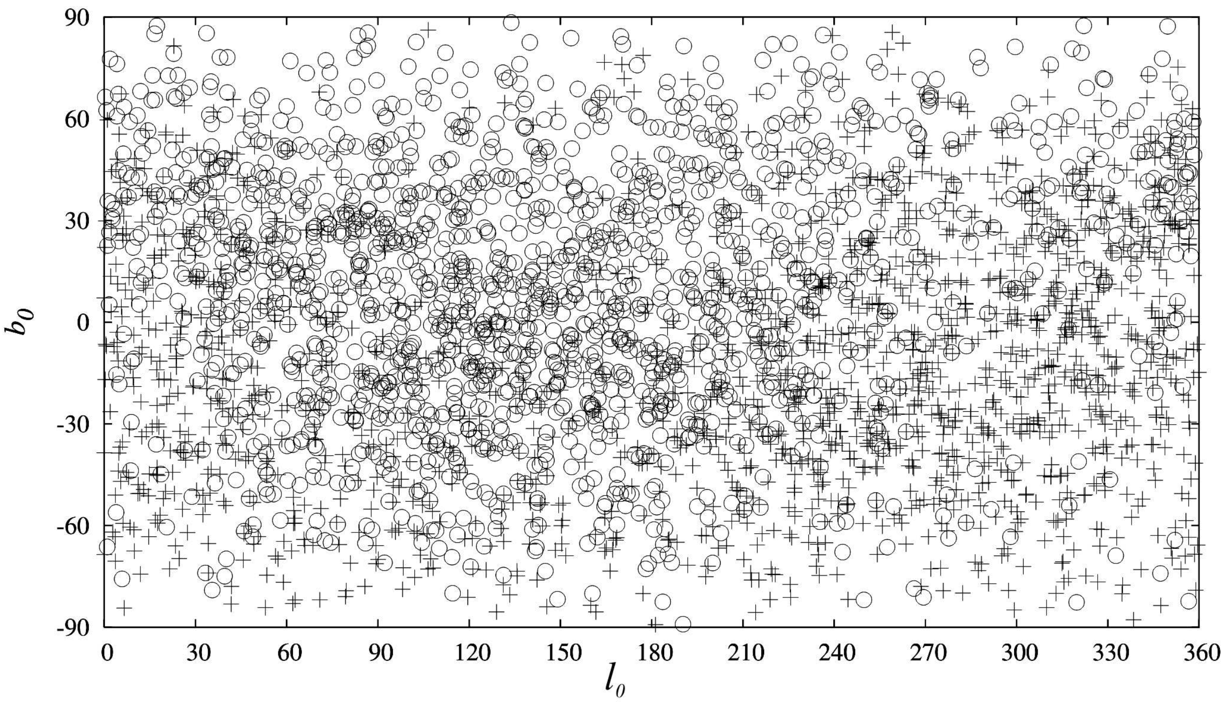

Fig. 2. *Poles of random distribution* (○) *in* i *and* Ω, *and with the same* α, δ, *as well as the corresponding mirror ones* (+), *resulting from Procedure* **a**.

sing 252 visual binaries with known ascending nodes, was studied to conclude that the orbital planes "do not show any trend to be parallel to the galactic plane" (Głębocki 2000).

In all these studies no specific rule concerning the orientation of orbital planes has been indicated. In most cases, only a conclusion that the number of binaries with reliably known orientation is still too small, i. e. that a reliably determined ascending node is available for a too small number of binaries, has been found. This fact is encouraging for the present authors to form a sufficiently large sample for the purpose of carrying out a qualitative analysis of the orientations of the orbital planes of binaries with known orbits. Namely, the ambiguity of the ascending node offers two alternative possibilities. The first is to calculate the pole for a given Ω (say, taken from a catalogue), whereas the other one is to assume that the ascending node becomes $\Omega + 180°$, in other words to calculate the so-called "mirror" pole, while the dilemma which of the two poles is the true one remains. In the present paper an attempt is made to derive the real orientations of orbital planes by assuming both values for the pole (pole and mirror one) and by using the sufficiently large sample of binaries.

2. BASIC IDEA

The present study starts from the following. If it is unknown, for a given binary, which of the nodes is ascending, or descending, then for this binary two positions for the orbital pole are possible: "true" pole (Ω among the input data) and the "false" one ($\Omega+180°$ among the input data), also called mirror pole. It is clear that it is unknown which of the two poles is the actual one. Therefore, for N orbital stars $2N$ poles can be obtained. Their presentation in the galactic coordinates will give the view of the distribution of N "true" orientations, but patchy due to the presence of an equal number of "false" poles or "mirror poles". This can be done by using observational data.

The authors compared such an "observational" distribution of poles (expected to be isotropic) with a random pole distribution. The random pole distribution is obtained in two ways, by applying the Procedure **a.** or the Procedure **b.**

[Procedure **a**] The poles are calculated with the same formulae as those used in the treatment of the observational material (relations (1)), but the input data are:

(i) true coordinates of binaries (α, δ)

(ii) amounts for i and Ω ($0° \leq i \leq 180°$, $0° \leq \Omega \leq 180°$), chosen at random for N poles, whereas for the next N poles the input is the same with Ω corrected by 180°. To choose at random i and Ω means to use the Monte Carlo method (Press et al. 1986). In this way this procedure is fully identical to the one applied in the case of the pole calculation for the observational material (except that input quantities are chosen at random). For the fictive stars used in the calculation of random poles the same coordinates α, δ, as for the sample ones, are assumed in order to avoid any selective influence of the positions.

[Procedure **b**] In this procedure the random poles (l_0, b_0) are chosen directly, without using formulae (1). The choice is again effectuated by applying the Monte Carlo method. After this, the positions are normed in order to be presented in the plane projection, i.e. in the rectangular coordinate system (l_0, b_0), (Popović 1993).

3. OBSERVATIONAL MATERIAL AND RESULTS

Our examinations are based on the data from the Sixth Catalogue of Orbits of Binaries (Hartkopf and Mason 2001 - hereinafter referred to as the Catalogue) since it is the most recent catalogue of this kind. Consequently, it offers a complete sample of known binary orbits. The Catalogue contains 1675 binaries, but the ascending nodes are unambiguously known only for 29 of them. However, to the method used here, this circumstance is not of a high significanse, as already noticed.

The positions of both kinds of poles, those following from the values given in the Catalogue, and for the corresponding mirror ones are presented in the same figure - Fig. 1 (where α, δ, i and Ω from the catalogue, i. e. α, δ, i and $\Omega + 180°$ are used as the input data). The former ones are represented by empty circles, the latter ones, equal in number, as crosses. The grades describing the orbit quality, specified in the Catalogue, are also indicated by the size of the circles/crosses. It can be seen from Fig. 1 that for both groups (empty circles and crosses) there is a region of a stronger concentration. For the obtained figure it is unknown which poles are true (they can be among both empty circles and crosses), or false, but it is sure that the figure contains the full number of true poles and also the full number of false ones. The same figure also contains the poles for binaries with known ascending nodes (filled circles, their total is 29 only), but, for obvious reasons, the false poles are not given for them. Therefore, the total number of poles presented in Fig. 1 is 3321 (1646 "true" poles without possibility of identification + 1646 their mirror poles + 29 known poles).

4. CONCLUSION

Even without any special statistical treatment, the results indicate that there is no global difference between the distributions of the "observed" poles (Fig. 1) and of the random ones (Procedures **a** and **b**, Figs. 2 and 3, respectively). It is logical to

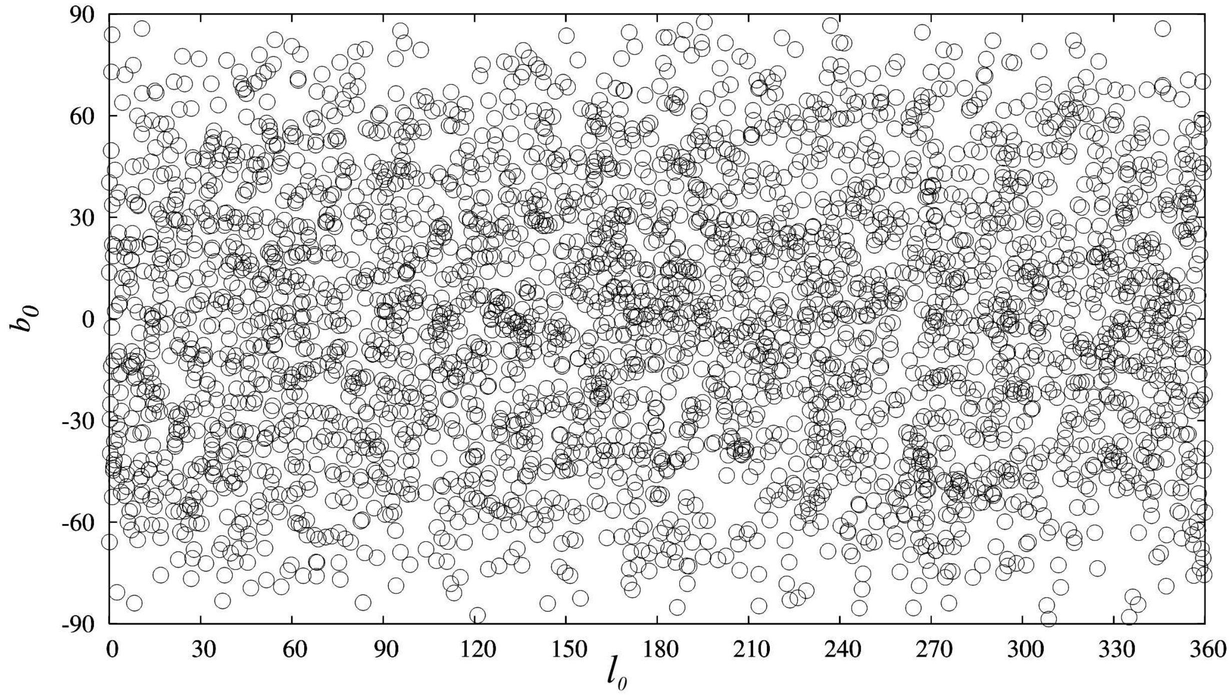

Fig. 3. *Random distribution in l, b coordinates with projection effect included, resulting from Procedure* **b**.

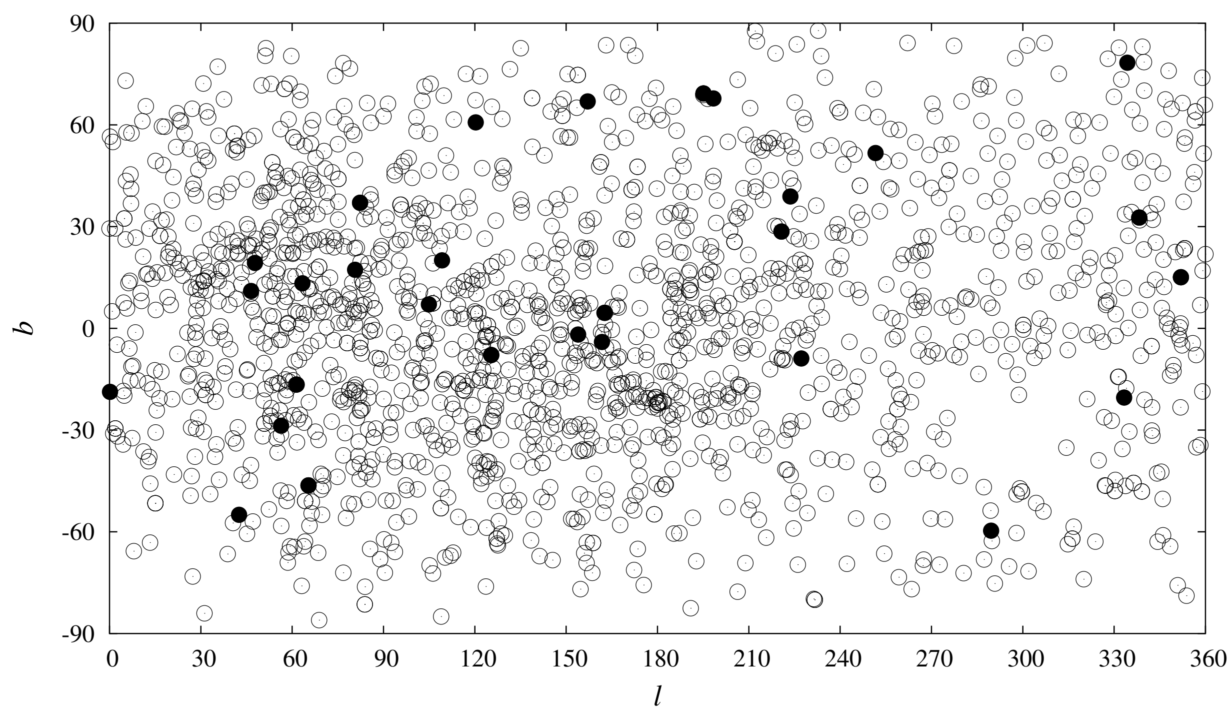

Fig. 4. *Distribution of binary positions (○) in the sky in galactic coordinates. Sign (●) indicates stars with known ascending node.*

Table 1. The Data on the Binaries with known Ascending Node

WDS	Name			ADS	$i[°]$	$\Omega[°]$		Orbit's author	$l_0[°]$	$b_0[°]$
01083 + 5455	WCK	1	Aa		109.5	47.4	1981	Lippincott, S.L.	236.65	50.65
01398 − 5612	DUN	5	AB		142.824	13.116	1957	van Albada, G.B.	171.05	47.14
04149 + 4825	STT	73	Aa,P	3071	74.	296.	1925	Alden, H.L.	110.15	65.04
04367 + 4116	58	Per			81.	237.	1993	Heintz, W.D.	113.00	70.21
05167 + 4600	ANJ	1	Aa	3841	137.18	40.8	1994	Hummel, C.A. et al.	347.46	38.01
06451 − 1643	AGC	1	AB	5423	136.53	44.57	1960	van den Bos, W.H.	67.00	49.08
08468 + 0625	STF	1273	AB-C	6993	39.	49.3	1996	Heintz, W.D.	181.54	14.15
09285 + 0903	STF	1356		7390	66.05	325.69	1976	van Dessel, E.	169.61	−4.53
10557 + 0044	BU	1076		7982	119.6	214.2	1970	Morel, P.J.	61.29	8.05
11111 + 3027	STT	231	AB	8083	91.50	83.10	1960	Hopmann, J.	103.57	0.34
11182 + 3132	STF	1523	AB	8119	122.13	101.85	1995	Mason, B.D. et al.	87.63	−27.92
11182 + 3132	ξ	UMa	Aa	8119	94.9	263.5	1995	Mason, B.D. et al.	103.16	−4.50
11182 + 3132	ξ	UMa	Aa	8119	91.	318.	1996	Heintz, W.D.	65.00	12.68
11387 + 4507	STF	1561	AB	8250	125.86	271.24	1994	Hale, A.	93.04	−49.34
13007 + 5622	BU	1082		8739	51.0	274.5	1981	Heintz, W.D.	120.09	9.71
13169 + 1701	BU	800	AB	8841	93.41	104.66	1994	Hale, A.	110.55	5.05
14575 − 2125	H N	28	AB	9446	72.53	317.31	1994	Hale, A.	200.77	70.38
16294 − 2626	GNT	1		10074	86.3	273.0	1960	Heintz, W.D.	91.43	43.69
17053 + 5428	STF	2130	AB	10345	144.7	282.8	1981	Heintz, W.D.	217.16	−38.78
18058 + 2127	STT	341	AB	11060	77.0	270.8	1982	Heintz, W.D.	131.86	24.41
18232 − 6130	GLE	2	Aa,P		89.	187.	1946	Alden, H.L.	301.93	65.32
18359 + 1659	STT	358	AB	11483	119.	30.8	1995	Heintz, W.D.	164.31	−34.90
18570 + 3254	BU	648	AB	11871	114.8	48.2	1994	Heintz, W.D.	175.08	−21.56
19064 − 3704	HJ	5084			149.6	50.3	1986	Heintz, W.D.	151.43	6.78
19121 + 4951	STF	2486	AB	12169	119.06	255.22	1994	Hale, A.	200.42	−2.39
20374 + 7536	HEI	7			21.	340.5	1993	Heintz, W.D.	103.37	40.45
20467 + 1607	STF	2727		14279	148.78	88.06	1994	Hale, A.	211.16	31.26
21158 + 0515	WRH	35			151.5	33.9	1992	Armstrong, J.T. et al.	208.84	15.72
21567 + 6338	WRH	36			90.65	310.6	1960	Fredrick, L.W.	196.96	10.95
22266 − 1645	SHJ	345	AB	15934	44.13	294.55	1994	Hale, A.	71.59	−16.86
22288 − 0001	STF	2909		15971	135.87	364.64	1984	Heintz, W.D.	187.65	35.10
22288 − 0001	zet2	Aqr	Aa-P	15971	34.3	202.7	1984	Heintz, W.D.	54.71	−13.23

expect that about half the poles presented as circles may become poles presented by crosses and vice versa. Due to this effect, the global distribution will not be violated. On the basis of this logical statement it is possible to draw the following conclusion: no SPECIFIC global distribution in the orientations of orbital planes exists.

There is also something else to be added: before calculating the "observed" poles, all the ascending nodes exceeding 180° were corrected by subtracting the excess amount from 180°. In this way the prominent pole concentrations presented as (○), i. e. as (+), are obtained. This correction has no influence on the general distribution of points in Fig. 1.

The random poles obtained by Procedures **a** and **b** are given in Figs. 2 and 3, respectively. Each figure contains 3292 poles (29 certain ones are not given). In Fig. 3 all the poles are given as circles because they are obtained by direct random choice. Fig. 4 gives the galactic coordinates for the 1646 used pairs without certain ascending nodes and for the 29 cases (filled circles) with known ascending nodes.

In order to make the calculation of pole positions more clear Eqs. (1) and with regard that, in the Catalogue, there are only 29 binaries with known ascending nodes, we present, in Table 1, the input and output data concerning the pole calculation for these 29 systems ((●) in Fig. 1).

Acknowledgements – This research has been supported by the Ministry of Science and Environmental Protection of the Republic of Serbia (projects No 1221 - GPM, RP and 1468 - SN). The authors are also grateful to Professors Dr Peter Brosche and Dr José Ángel Docobo Durántez for useful suggestions.

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НАГИБИ ОРБИТАЛНИХ РАВНИ ДВОЈНИХ СИСТЕМА

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UDK 521.328
Стручни рад

Анализирани су нагиби орбиталних равни двојних система коришћењем комплетног узорка познатих орбиталних система. Закључено је да се глобална расподела посматраних оријентација орбиталних равни не разликује од расподеле симулираних случајних оријентација. У оба случаја задржани су исти положаји звезда.