THE SPECTROSCOPIC ORBIT OF δ ANDROMEDAE

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Abstract

From radial velocity determinations made over the last 75 years, the period and the orbital elements of δ And have been derived.

Introduction. The bright star δ And is the visual binary ADS 548, which includes a 12th magnitude component 28 seconds of arc from the brighter star. Although micrometric observations do not indicate any measurable orbital motion, the companion appears to share in the proper motion of the primary. It can be assumed, therefore, that the pair forms a physical system of very long period. For the brighter star (V=3$^{m}_{.}$25, spectral type K3 III), there exist a large number of radial velocity observations, made at the Lick, Victoria (DAO), Mount Wilson and David Dunlap Observatories. (The latter include those obtained by the author).

Campbell (1928) found that the star exhibits small-range velocity variations. Therefore, the assumption is made that δ And is a spectroscopic binary in addition to being a wide visual pair.

The Orbital Elements. A total of 32 radial velocities have been collected in Table I. The first column gives the J.D. of observation arranged in the order of increasing phase. The phases in column two have been computed by means of the formula

$$\text{Phase} = \text{J.D.} \times P^{-1},$$

where P = 15,000 days (about 41 years). The period was derived from a graphical representation of velocity as a function of time. Although the period is approximate, it appears to be the best choice of three different assumptions between 14 and 17 thousand days. (In Bakos (1974), the period was given, by mistake, as 150 days.)

The third and fourth columns of Table I contain the radial velocity of the star, reduced to the Lick system (Wilson 1953) and the *O-C* resulting from the preliminary orbital elements. The velocity curve has been plotted in figure 1. There is a large scatter in the observational points presented in the plot, owing presumably to the variable quality of the observational data. The dashed line represents the radial velocity of the system while the full

TABLE I

RADIAL VELOCITY OBSERVATIONS OF δ AND

Date	Phase	V_r	$O–C$	Source
J.D. 2415618	0.038	− 4.6	−1.5	Lick
6732	0.104	− 4.1	+0.3	Mt. Wilson
6771	0.106	− 4.7	−0.3	"
6772	0.106	− 2.3	+2.1	"
6775	0.106	− 3.6	+0.8	"
6778	0.107	− 2.5	+1.9	"
6794	0.107	− 3.9	+0.5	Lick
7094	0.125	− 4.8	+0.3	"
2417798	0.166	− 7.2	−2.1	"
2435393	0.201	− 7.6	0.0	DDO
2435402	0.202	− 7.5	+0.2	"
2418917	0.232	− 8.8	−0.3	Lick
9011	0.238	− 8.5	+0.1	"
9255	0.252	− 8.8	+0.2	"
9370	0.259	−12.7	−3.6	"
2419397	0.260	−10.0	−0.8	"
2422236	0.424	−11.0	+1.5	"
2913	0.467	−11.8	−0.1	"
2422966	0.470	−12.0	−0.3	DAO
2440434	0.498	−11.3	+0.5	DDO
0455	0.499	−11.2	+0.6	"
0469	0.500	−10.6	+1.2	"
2441606	0.566	−12.1	−0.2	"
2428030	0.768	−10.0	+0.3	"
8800	0.813	− 9.0	+0.4	"
8822	0.815	− 9.9	−0.5	"
2428856	0.816	− 6.9	+2.5	"
2414169	0.955	− 7.8	−2.7	Lick
4522	0.974	− 4.5	−0.2	"
4532	0.974	− 5.9	−1.6	"
4556	0.976	− 2.1	+2.2	"
2414567	0.976	− 5.8	−1.6	"

curve is the computed velocity curve based on the preliminary orbital elements.

A graphical method (Smart 1949) was used to derive preliminary orbital elements. These elements were then improved by a least-squares solution of the equations of condition, following the Lehmann-Filhés method (Aitken 1963). The results are presented in Table II.

Since δ And is a single-line spectroscopic binary, the mass function is

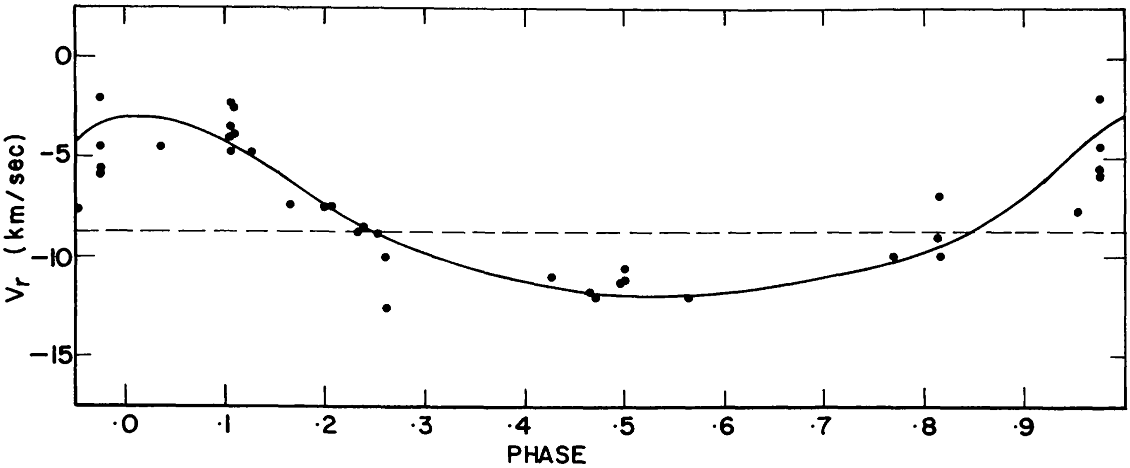

FIG. 1—The radial velocity curve for δ And.

TABLE II

ORBITAL ELEMENTS OF δ AND

Element	Preliminary	Least-Squares
P (days)	15,000	
T_0 (J.D.)	2415538	2415568
ω (degrees)	356.9	356.1 ±5.2
e	0.28	0.34±0.14
K (km/sec)	4.4	4.0 ±2.7
γ (km/sec)	−8.8	−8.5 ±0.2
$a_1 \sin i$ (10^6 km)		785
$f(m)$ ($M_\odot$)		0.0057

the only parameter available for estimating the physical properties of the system. If one can make some reasonable assumption about the masses of the two stars, both the inclination of the orbital plane and the size of the relative orbit can be estimated. However, because of the "funnel effect" of their evolutionary tracks in the H-R diagram, the masses of giant stars can vary within a wide range. According to Allen (1973), the (interpolated) mass of a K3 III star is 4.5 $M_\odot$, a value which will be assumed for the mass, M_P, of the primary. In addition, the secondary star will be assumed to lie on the main sequence and to be one magnitude fainter, in the photographic region, than the primary. According to the author's unpublished determination, the absolute visual magnitude of the primary is $M_V = 0.58$ and the colour index is $B\text{-}V = 1.28$. The above assumptions then indicate a secondary star of spectral type F0, with a mass of approximately $M_S = 1.8\ M_\odot$. For these values of M_S and M_P, the value of the mass function corresponds to an inclination of the orbital plane of $i = 20°$. The semi-major axis, a, of the relative orbit, according to Kepler's harmonic law, is then 47 AU. If the total mass of the system is reduced, keeping the ratio of the two masses fixed, these values do not change appreciably. For instance, if $M_P = 2.5\ M_\odot$ (a reasonable lower limit for the mass of the primary) and $M_S = 1\ M_\odot$, then $i = 24°$ and $a = 39$ AU.

Conclusions. It has been shown that δ And is a long-period spectroscopic binary. In order to improve its orbital elements additional spectrograms would be desirable. The velocity curve is now on its ascending branch approaching a maximum. Because it is a bright star, however, there may exist many more unmeasured and unpublished radial velocities in files of observatories, which could be used for a further study of the system.

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