LONG-TERM RADIAL VELOCITY VARIATIONS OF o And*

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Abstract. The results of radial velocity measures of the star o And from high dispersion plates relative to the years 1964, 1966, 1975 and 1976 are given. The averaged values of the 1964 and 1966 plates confirm the existence of the minimum in the trend of the radial velocities and fit well the curve obtained in the hypothesis of periodic long-term radial velocity variations with the period of 23.5 years (Fracassini *et al.*, 1977). Preliminary orbital elements in the hypothesis of a long period spectroscopic binary system have been tentatively drawn.

1. Introduction

o And (HD 217675, B6Ve) has long series of spectrographic observations dated since the beginning of the century. The complete bibliography of the star can be found in Fracassini *et al.* (1977), Gulliver and Bolton (1978), and Gulliver *et al.* (1980).

From a periodogram analysis of radial velocities (RV) since 1900, Fracassini *et al.* (1977) have found a long period of about 23.5 yr which was ascribed to a probable photospheric activity or to the presence of an invisible companion. This result was achieved independently from those obtained by the speckle-interferometry (Blazit *et al.*, 1977; McAlister, 1978, 1979; McAlister and DeGioia, 1979; McAlister and Fekel, 1980; Bonneau *et al.*, 1980). The procedure for the study of long-term RV variations was applied also to other Be stars (Pastori *et al.*, 1982; Antonello *et al.*, 1982). The period of 23 yr found for o And was questioned by Harmanec *et al.* (1977) and Gulliver and Bolton (1978) and further confirmed by Fracassini and Pasinetti (1977). Moreover the hypothesis of a period of about 26 yr was later advanced by Horn *et al.* (1982) from spectrographic observations.

This work deals with some results of radial velocity measures from high dispersion plates, which seem to confirm the period found in our previous paper and the possible long-period spectroscopic binariety of o And.

2. Observations and Reductions

We have measured RV of hydrogen lines on six plates taken in the period 1964–1966 when o And was a normal B-type star (Pasinetti, 1968) and RV of hydrogen line cores on fives plates of the years 1975–76 when the star undergone a shell-phase. This material was taken at the 98 and 30 inch telescopes of the

* The results are partly based on observations made at the Haute-Provence and Royal Greenwich Observatories.

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TABLE I
Radial velocities of hydrogen lines (km s^{-1})

Plate	Dispersion Å mm^{-1}	J. D. 2400000 +	Hα	Hβ	Hγ	Hδ	H8
362	10	38662.477		− 10.2	− 26.0	− 59.4	− 40.0
366	10	38663.383		− 14.8	− 49.2	− 47.7	− 65.8
371	10	38665.434			− 48.5	− 48.2	− 58.7
383	10	38668.434		− 3.0	− 45.8	− 75.1	− 18.3
974	10	39392.387		− 30.5	− 40.0	− 44.3	− 18.8
976	10	39393.340		− 34.2	− 43.6	− 43.6	− 42.4
4324	8.5	42645.527			− 23.4	− 10.9	
GB 3429*	12.5	42679.535	− 19.6				
GB 3430	12.5	42679.551		− 25.7	− 21.2	− 17.7	− 15.2
GB 3717	12.5	42972.539		− 21.7	− 24.0	− 16.7	− 22.6
GB 3870*	12.5	43090.395	− 18.7	− 19.9			

GB: Haute-Provence Observatory plates.
* Red plates.

Royal Greenwich Observatory and at the 1.52 m of the Haute-Provence Observatory, and was kindly placed at our disposal by Dr D. Stickland and Dr R. Faraggiana, respectively. The plates were measured with visual digitized comparator of the Merate Observatory supplied of a Heidenhain grating (1 μ accuracy). The results of the RV and the data of observation are given in Table I. The measurements of the hydrogen-line cores included lines from H_α to H_8; H_ϵ line was rejected owing to its blending with the Ca II λ 3968 line. The mean error is ± 3 km s^{-1} for the English plates and ± 4 km s^{-1} for the Haute–Provence plates. The RV values have been averaged for each spectrum and for each month according to the procedure described in Antonello *et al.* (1982).

3. Results and Discussion

Figure 1 shows the general trend of RV of o And in this century. The RV are taken from Table III of Fracassini *et al.* (1977) with the exception of the data of the years 1975–76 relative to the shell-phase. The RV values were averaged from H_α to H_8 for single spectra and from all the spectra for each month. We have also included the averaged RV values of hydrogen line wings obtained from Table I of Gulliver and Bolton (1978). Unfortunately all the data found in the literature are not suitably spaced in time. In spite of the scattering of the observationals points, Figure 1 shows long-term RV variations; in particular the averaged RV obtained from the results of Gulliver and Bolton (1978) and of four high dispersion plates (this paper) show a decrease in the last years (1976–79). The minimum of the values of RV falls between the years 1962–66 when the spectra were of normal B-type; however, in general, the spectroscopic behaviour described by Pasinetti (1968) and Gulliver *et al.* (1980) does not seem correlated with the general trend of RV, though this may be due to the lack of

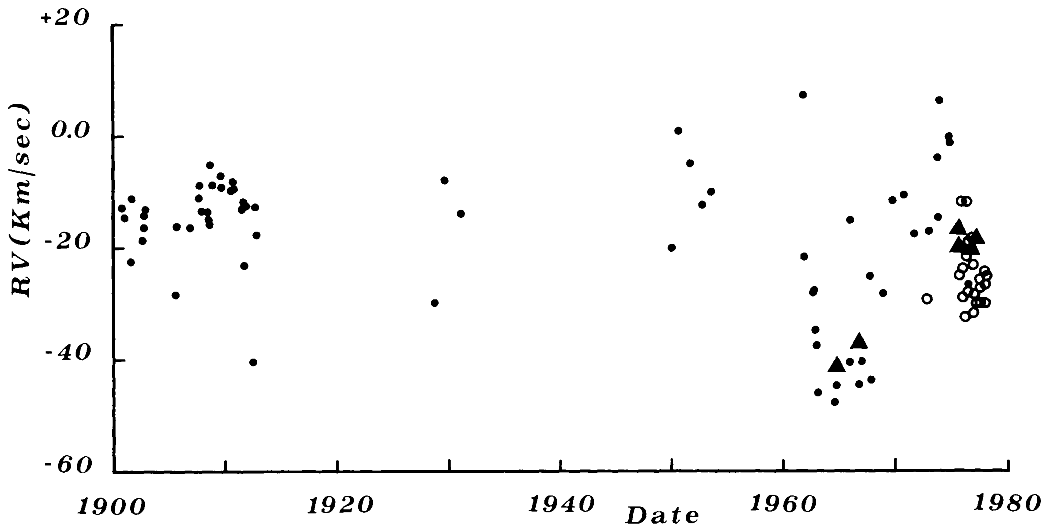

Fig. 1. Averaged RV of hydrogen lines vs date. ● Table III of Fracassini *et al.* (1977). ▲ Averaged RV values from the measures of high dispersion plates (present paper). ○ Averaged RV values obtained from Table I of Gulliver and Bolton (1978).

data in some intervals of time. Figure 2 shows the averaged RV values vs the phase computed with the period $P = 23.5$ yr (Fracassini *et al.*, 1977).

This period depend heavily upon the minimum of RV in the years 1962–66. The data obtained from high dispersion plates relative to these years are represented in Figure 2 by two triangles. The corresponding values are the average of the results of four and two plates, respectively, and therefore have high weight. These data, which agree well with the curve drawn by the previous points confirm the reality of the minimum of RV and the periodical trend. Unfortunately we have not found in the literature, results for the years 1939–43 and 1916–1920 when the other minima would be occurred; if plates of these periods should be available, the long-period variations of the RV could be confirmed. The data of Gulliver and Bolton (1978) scatter down from the curve (Figure 2) of about 15 km s^{-1}; at present we have not a clear explanation for these RV values, however, according to these authors, it is possible that, in those years, the hydrogen line wings formed in an expanding atmosphere so they are not representative of the motion of the star as a whole.

4. Dynamical Hypothesis

According to Harmanec and Kříž (1976) all the Be stars are binaries with mass exchange between the components. In the hypothesis that the curve, shown in Figure 2, should be ascribed to a binary motion, we have drawn the preliminary orbital elements (Table II). The results give a high value of the mass function ($f(m) = 3.8$). This is not surprising if we consider the complex phenomena which occur in the Be stars. Probably the available RV data are still too scattered to

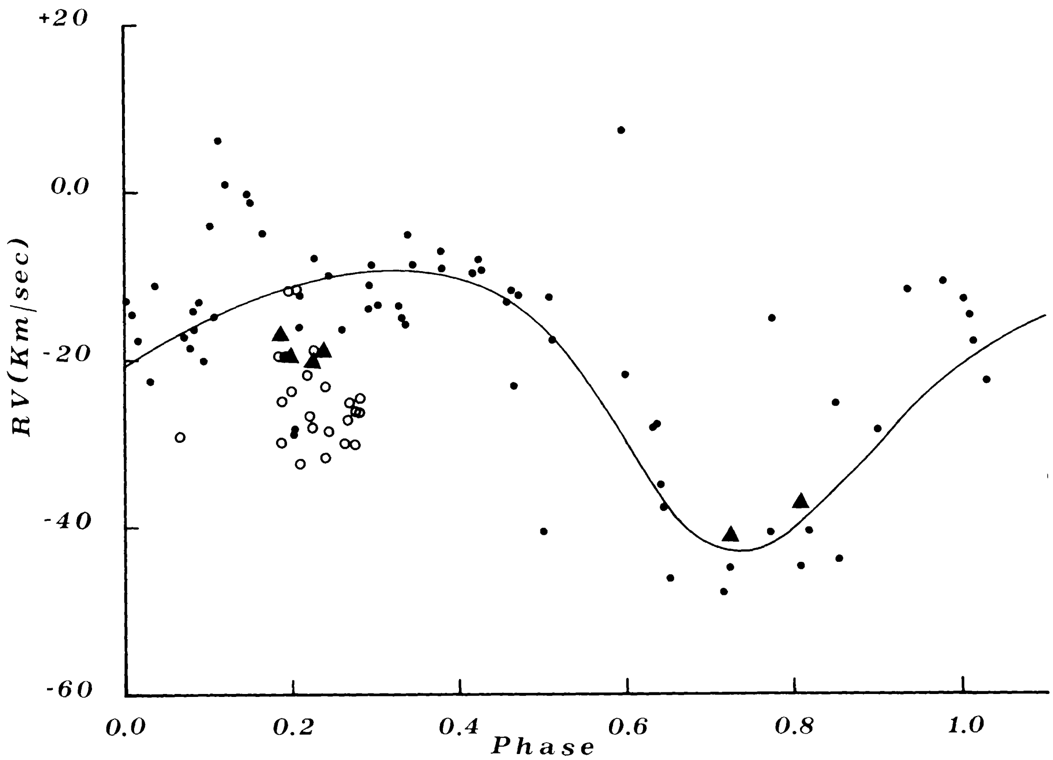

Fig. 2. Averaged RV of hydrogen lines vs phases (P = 23.5 yr). See Figure 1 for the symbols.

TABLE II
Orbital elements for o And

P (yr)	23.5
γ(km s^{-1})	-22.3
K(km s^{-1})	16.7
e	0.22
ω(°)	172
T(J.D.)	2439050.
a sin i (U.A.)	12.8
Mass function ($M_\odot$)	3.8

draw a suitable RV curve. We noted that our value of the orbital period is quite similar to that proposed by Horn *et al.* (1982). These authors have used different spectroscopic material. On the contrary the other orbital parameters are different from our ones; as the authors do not specify the adopted assembling procedure of the RV data, a comparison between these results is not possible. Moreover all the available RV for o And listed in Table I by Horn *et al.* (1982) have been reassembled with the process described by Antonello *et al.* (1982) but we do not obtain the RV curve shown in Figure 2 of the paper by Horn *et al.* (1982).

From the results of the speckle interferometry, Blazit *et al.* (1977), McAlister (1978, 1979), McAlister *et al.* (1979, 1980), and Bonneau *et al.* (1980) have evidentiated a distant and a closer companion of o And. If we assume the spectroscopic parallax to be 0″.007 (Hoffleit, 1964), the angular separation of the components 0″.34 and 0″.057, and the total mass of the system $10M_{\odot}$, we obtain as projected orbital radii $r_1 = 49$ AU and $P_1 = 107$ yr for the distant companion and $r_2 = 8$ AU and $P_2 = 8$ yr for the closer companion. Of course these values are rough estimates of the true periods; we may identify our 23 yr period companion with the close component.

Ivanov (1976) has considered the effects of an encounter between a contact binary system and a field star. This encounter may induce changes in the orbital eccentricity, periodic collisions between the components and mass loss of the contact binary system. On these bases a possible model for o And can be hypothesized. Taking into account the debatable hypothesis of a contact binary system proposed by Schmidt (1959) and later supported by Fracassini *et al.* (1979), we can infer that similar phenomena may be induced by the 23 yr period companion; the periodic shell phenomenon (Fracassini and Pasinetti, 1975) may be ascribed to the influence of the periastron passage of the third body on the contact binary. In this model o And would be a multiple system with four bodies: the contact binary stars, the close and the distant stars.

5. Conclusions

We have measured RV of hydrogen lines and hydrogen line cores of eleven high dispersion plates. The obtained averaged values of the years 1964–66 confirm the minimum of RV in these years and fit well the curve drawn with the assumption of a RV periodicity of 23.5 yr. In this hypothesis another minimum of RV (Figure 2) may be foreseen at the end of this decade (1986–89). The periodical trend may be interpreted either as long-term oscillation of the atmosphere, like other Be stars, or due to a binary motion. The hypothesis of a multiple system is supported by the results of the speckle interferometry which has discovered two companions of o And (Bonneau *et al.*, 1980) and by the results obtained later by Horn *et al.* (1982) who have found a rather similar period.

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