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The three-body system V 505 Sagittarii

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Abstract. It is known that the period of the eclipsing binary V 505 Sgr changes, and that the changes can be explained - at least partly - by a light-time effect. The system is also known as a speckle binary. In this paper parameters of the third body orbit are suggested in order to explain both sets of data. Some discrepancies in the size of the orbit and radial velocity data remain. Next periastron passage should be at 1998.9.

Key words: binaries: eclipsing – binaries: visual – stars: individual: V 505 Sgr

1. Introduction

In several cases, eclipsing binaries are members of a close visual binary (e.g., V822 Her, δ Ori, V1031 Ori, V Pyx, DN UMa). Recently visual components were discovered by speckle interferometry for eclipsing binaries V 505 Sgr (McAlister et al. 1987, 1993) and SZ Cam (Mason 1995). To explain the behaviour of times of minima, presence of the light-time effect due to a third body for both systems was suggested - by Chambliss et al. (1993) for V 505 Sgr, by Mayer et al. (1994) for SZ Cam. Light-time effect might be found for some of the binaries mentioned too.

When radial velocity data have been measured for a visual binary with a known orbit, then masses of components and distance of the system can be determined. However, if the period is longer than one or two decades the spectroscopic data might not be of sufficient accuracy. In case the component is an eclipsing binary then the light-time effect can play a role identical to the spectroscopy.

V 505 Sgr (HR 7571; HD 187949) is an Algol-type system, with the primary component of spectral type A2 V, the secondary component G4 IV, and with a third body with spectral class near F8 (Tomkin 1992). Magnitude in maximum is V = 6.48, minimum depths are 1.2 and 0.25 mag (V), period 1.183 d. Recent radial velocity study was done by Tomkin (1992), light curves were solved e.g. by Walker (1993) and Chambliss et al. (1993).

In the following an attempt will be made to join the observed times of minima with data from speckle interferometry to find preliminary parameters of the third body orbit of the V 505 Sgr system. Interesting is probably the length of the period (connected with a forecast of the next periastron time).

2. The data

The times of minima were collected by Chambliss (1972), Rovithis-Livaniou and Rovithis (1992) and by Chambliss (1993; photoelectric data only). Newer photoelectric minima were published by Rovithis-Livaniou & Rovithis (1994) and by Müyesseroğlu et al. (1996). The photoelectric data are not numerous; they are presented in Fig. 2. In this graph, the ephemeris

$$\text{Pri. Min.} = \text{JDhel.}2425501\overset{\text{d}}{.}3871 + 1\overset{\text{d}}{.}1828688 \cdot E$$

(which resulted from first attempts to account for the light-time effect) is used. From eight photographic times published by Hoffmeister (1934) two mean minima are formed; the scatter of visual times is so large that they will not be considered here. One can see that the time of periastron had to occur at around JD 2437000 and that the orbital eccentricity is considerable.

The speckle interferometry data by McAlister et al. (1993) are repeated in Table 1 and plotted in Table 2. It is apparent that these measurements were made after an apoastron passage.

The radial velocity measurements as published by Tomkin (1991) are: 1.9 ± 1.4 and -5 ± 5 km/s for the primary and secondary component systemic velocities, for the tertiary component the velocity was -9 for JD 2444000 and -13 km/s for JD 2448000, with scatter of about 2 km/s. We will however show that data of higher accuracy would be needed for comparison with the expected values.

The formulae which describe the light-time effect (and the accompanied changes of radial velocities) are given e.g. by Mayer (1990) [1] , formulae for the separation and position angle in the visual orbit are e.g. in Aitken (1935).

Combining the $O-C$ behaviour (Fig. 2) and the speckle data (Fig. 2) it was possible to find parameters of the third body orbit as they are given in Table 2. This orbit satisfies also the photographic data; if the photographic data are not used in the solution, the resulting parameters differ only insignificantly. Since

[1] Please note that in Mayer (1990) as well as in Chambliss et al. (1993) there is a missing square root mark in nominator in the formula for $O - C$.

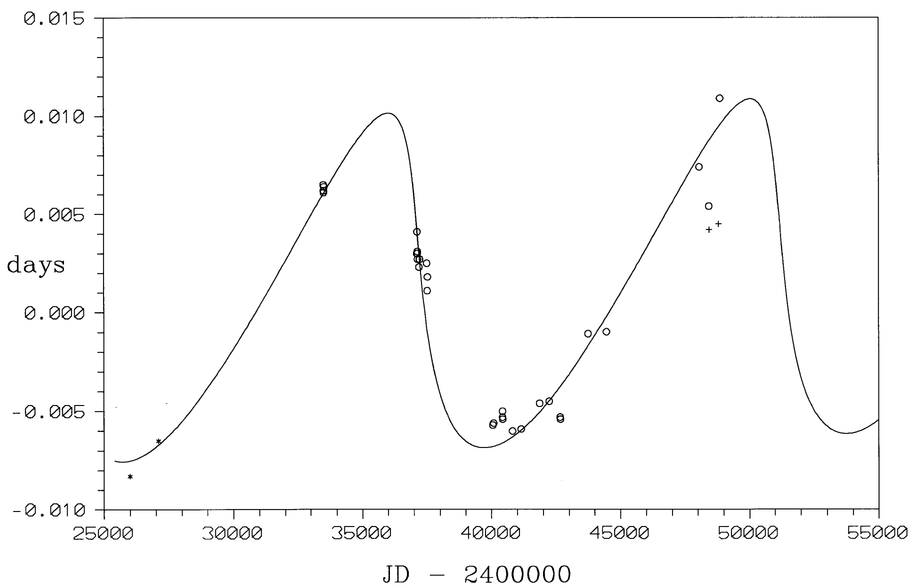

Fig. 1. $O - C$ diagram for V 505 Sgr. Circles are photoelectric data for primary minima, crosses for secondary minima; asterisks are for photographic data. The curve corresponds to the light-time effect due to a third body with the orbit according to Table 2.

Table 1. Interferometric data as given by McAlister et al. (1993)

Time	JD 2400000+	Pos. angle deg	Separation arcsec
1985.5150	46254	189.6	0.302
1985.8425	46374	189.8	0.311
1989.3069	47639	181.0	0.261
1990.3445	48018	176.9	0.246
1991.3903	48400	173.4	0.234
1991.7124	48517	173.3	0.226
1992.4497	48786	171.7	0.214

Table 2. The parameters of the third body orbit

Element	Units	
Long period P	year	38.4
Semiamplitude A	day	0.0086
Eccentricity e		0.77
Length of periastron ω	deg	167
Time of periastron	JD	2437100
JD_0		2425501.3881
Short period	day	1.18286886
$f(M_3)$	$M_\odot$	0.00775
Inclination i	deg	26.9
Nodal line position angle Ω	deg	188
Semiamplitude γ_{12}	km/s	2.7

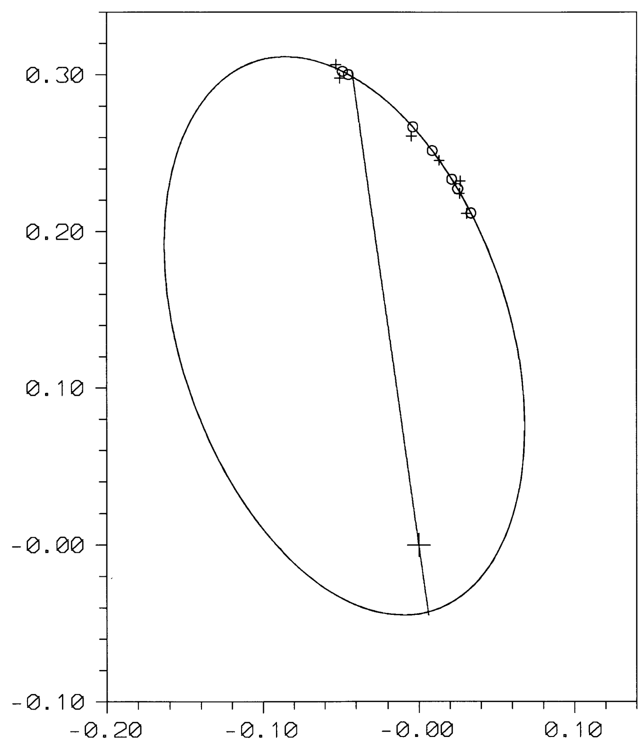

Fig. 2. The visible relative orbit of the third body. The cross marks the position of the eclipsing pair, the plus signs correspond to data by McAlister et al. (1993; see Table 2), circles to calculated positions; the curve is calculated for the distance 102 pc. Scales on both axes are in arcsec, north is down, east to the right.

the secondary minimum times differ from the trend of the primary minima, the secondary minima are not considered. (From the two cases it is difficult to speculate if this difference is due to lower accuracy - the secondary minima are shallow - or due to orbital eccentricity. In an Algol system, zero eccentricity is of course expected.)

3. Discussion

In the case of V 505 Sgr the masses of all three components are known: Tomkin (1991) gives: M_1 = 2.20 and M_2 = 1.15 $M_\odot$, Chamblis et al. (1993) estimates M_3 = 1.20 $M_\odot$. Therefore - if the orbital period P is known - the semimajor axis of the orbit follows from the Kepler's law. The period is constrained by the speckle data; having in mind the constraints on the other orbital elements due to both sets of data, it proved to be impossible to represent the speckle data by a period differing from that given in Table 2 more than about 1.5 years. The inclination follows from the mass function and can be written e.g. as

$$\sin i = 173.15 A M^{2/3} / M_3 P^{2/3} \sqrt{1 - e^2 \cos^2 \omega}\ .$$

The result is that the speckle measurements can be fitted only when the distance of the system from the Sun is around 100 ps (102 ps is the value for which the curve in Fig. 2 is drawn). However, the distance of the system can be reliably estimated as 128 $\pm$ 6 parsec (Tomkin 1991) using spectral classification and photometry.

Some possibilities to explain this disagreement can be suggested, it however seems to be premature to discuss them in detail until the elements are confirmed or revised be newer data.

Another discrepancy presents the difference in systemic velocity γ_{12} of the eclipsing pair and velocity of the third body. According to elements given in Table 2, this difference should not be larger than about 2.6 km/s in the time interval covered by observations (and the velocity of the third body should not change more than several tenths of km/s). It seems that it might be accuracy of radial velocity data which can be blamed for this disagreement (since there is no realistic third body orbit which would yield the large velocity differences published). Only during the periastron passage the difference of velocities might reach more than 10 km/s.

The orbital parameters found here must be considered as preliminary until new data are obtained. It is also necessary to point out that in Algol system, the times of minima need not to be effected by the light-time only; changes of period due to other reasons are common. To check it in the case of V 505 Sgr, new times of minima are badly needed. Since the next periastron passage is predicted for 1998.9, they can - provided speckle interferometry and spectroscopy continue - help to find reliable values of component masses and distance of this system soon.

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