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Preliminary Results for the Triple System AV CMi

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Abstract. New CCD photometric observations in V, R and I filters of the eclipsing binary AV CMi have been obtained. The complete light curves are analyzed with the Wilson-Devinney code and new geometric and photometric elements are derived. Moreover, 2-year systematic observations of the system revealed the existence of a third body orbiting around one of the components with an approximate period of 0.52 days. The first light elements for this additional component are given and its nature is discussed.

1. Introduction

The system AV CMi (= GSC 07700-0121 = 2MASS J07091084+1211190, $\alpha_{2000} = 07^h09^m10.84^s$, $\delta_{2000} = +12°11'19.1''$) has a period of 2.277751 days, an apparent magnitude of B=11.8 mag and it was discovered by Hoffmeister (1968). The system was generally neglected, and no complete light curve exists so far. The only information of its spectral type is given by Svechnikov & Kuznetsova (1990), while many times of minima have been published. The secondary component has an eccentric orbit, while the discovery of a third body with an internal orbit is presented for a first time in the current study.

2. Observations and analysis

In order to obtain a complete light curve (hereafter LC) of the system, the observations were carried out for 21 nights from December 2007 to March 2008, while for the tracing of the third body, systematic observations in I filter took place during the winters of 2008 and 2009. The system was observed at the Athens University Observatory, using a 40-cm Cassegrain telescope equipped with the CCD camera ST-8XMEI and the V, R, I Bessell photometric filters. Differential magnitudes were obtained by using the software Muniwin v.1.1.23 (Hroch 1998), while the stars GSC 0770-0929 and GSC 0770-911 were selected as comparison and check stars, respectively.

The LCs were analysed with the PHOEBE 0.29d software (Prša & Zwitter 2005) which uses the 2003 version of the WD code (Wilson & Devinney 1971; Wilson 1979). Due to the lack of spectroscopic mass ratio of the system, the q-search method was applied in Mode 2, 4 and 5 in order to find the most probable value of the (photometric) mass ratio (q_{ph}). In each Mode the method of Multiple Subsets was used in order to obtain the final photometric solution.

The values of the temperatures of the components were adopted according to the spectral classification of Svechnikov & Kuznetsova (1990), as F2 and G5, respectively. The minimum value of the weighted sum of the squared residuals was found in Mode 2. The q-search method in this mode converged to a mass ratio value close to 0.71, which was used as initial one and then it was adjusted in the subsequent analysis in the same Mode. The albedos $A_1,\ A_2$ and the gravity darkening coefficients $g_1,\ g_2$ were given their theoretical values according to the spectral type of each component. The synthetic and observed light curves and the q-search plot of AV CMi are shown in Fig. 1, the 3-D model of the system in Fig. 2 and the derived parameters from the light curve solution are listed in Table 1.

Table 1.: The parameters of AV CMi derived from the LCs solution

Parameter	*value*	*Parameter*	*value*			
$q\ (m_2/m_1)$	0.710 (2)		V	R	I	
i [deg]	83.8 (4)	x_1**	0.493	0.418	0.345	
e	0.11 (1)	x_2**	0.493	0.417	0.344	
T_1*[K]	7000	L_1/L_T	0.464 (1)	0.455 (1)	0.442 (1)	
T_2 [K]	7005 (6)	L_2/L_T	0.463 (2)	0.455 (2)	0.442 (3)	
A_1*=A_2*	0.5	L_3/L_T	0.073 (2)	0.090 (2)	0.116 (2)	
g_1*=g_2*	0.32		*Pole*	*Point*	*Side*	*Back*
Ω_1	6.04 (1)	r_1	0.190	0.194	0.191	0.193
Ω_2	5.29 (1)	r_2	0.176	0.180	0.177	0.179
χ^2	0.21699					

*assumed, **Van Hamme (1993), $L_T = L_1 + L_2 + L_3$

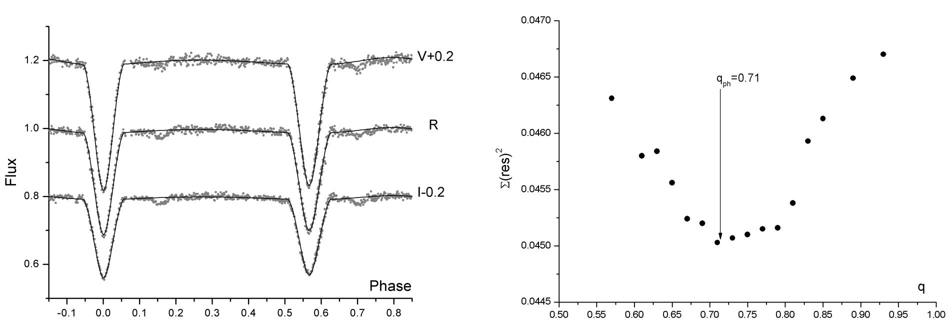

Figure 1.: Left panel: The synthetic LCs (black solid lines) along with the observed ones (gray points). Right panel: The q-search plot of AV CMi in mode 2.

3. Light elements of the third body

From our observations in VRI filters it was found that the maximum flux drop, during the transit of the third body in front of one of the components, occurs in I filter. We

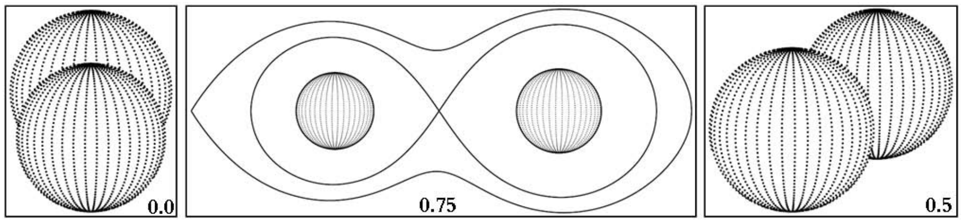

Figure 2.: The 3-D model of AV CMi in various phases.

managed to detect five transits of the third body (see Fig. 3), to calculate its orbital period and finally construct its light ephemeris, which is:
$T = HJD\,2454521.36315\ +\ 0.5192237^d\ \times\ E.$
The duration of the transit was found to be approximately 3.3 hrs, while the mean flux drop of the eclipsing binary was found to have a value of 2.6%.

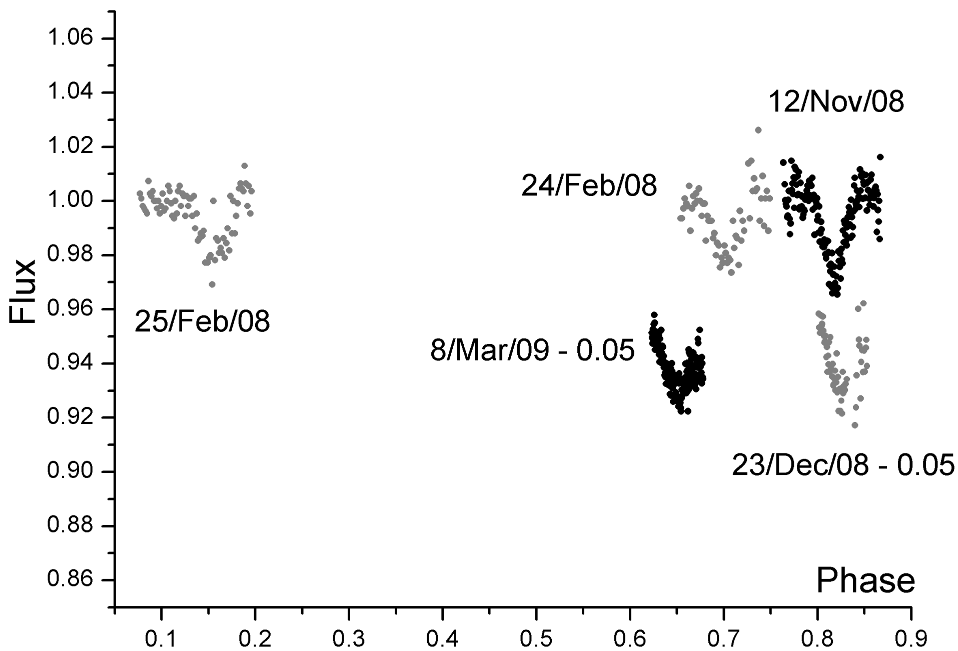

Figure 3.: The flux drop of AV CMi in I-filter due to the transit of the third body in front of one of the other components in various dates.

4. Discussion and Conclusions

Complete VRI light curves of AV CMi were obtained. The light curve analysis showed that the system is detached, and its components have almost the same temperature. The secondary component (less massive) was found to have eccentric orbit. Moreover, during the analysis a luminosity contribution of a third body was taken into account, since the observations revealed the existence of transits in front of one of the components of the system. The luminosity fraction of the third body was found to be $L_3/L_{Total} = 9.3(2)\%$, while the maximum luminosity contribution was found in I-filter, indicating its cool nature. It has an internal orbit, almost coplanar with the one of the eclipsing pair, and its period was found to be ~ 0.52 days. It is very difficult to conclude which component is eclipsed by the third body, since both of them have the same temperature. The 2.6% flux drop of the eclipsing binary indicates that the size of the third body is probably very small, and that is the reason we cannot observe its eclipse, but only its transit. Spectroscopic observations are certainly needed in order to: i) derive the mass ratio of the components of the eclipsing pair, ii) define the spectral types of all the components of the triple system, and iii) detect periodic shifts in the radial velocity curves due to the existence of the third body. Moreover, additional photometric observations in I-filter during the transits will help to determine the period of the third body with higher accuracy. To sum up, the preliminary results of the present analysis show that the third body is small and cool and it has an internal and eccentric orbit. These characteristics lead us to suggest that the third body is probably a brown dwarf or a massive Hot Jupiter(!), but its nature requires further study.

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