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 in an eccentric orbit around one of the components with an approximate period of 0.55 days. It was also found a small decrease in the total luminosity of the system, caused by the transit of the third body in front of one of the components of the eclipsing pair. 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, α_{2000} = $07^h09^m10.84^s$, δ_{2000} = +12°11´19.1´´) has a period of 2.277751^d, 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

In order to obtain a complete light curve 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.

3. Light curve analysis

The light curves were analysed with the *PHOEBE 0.29d* software (Prša & Zwitter 2005) which uses the 2003 version the Wilson-Devinney 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 (detached system), Mode 4 (semi-detached system with the primary component filling its Roche Lobe) and Mode 5 (semi-detached system with the secondary component filling its Roche Lobe) in order to find the most probable value of the (photometric) mass ratio (q). In each Mode the method of Multiple Subsets was used in order to obtain the final photometric solutions. 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. This value of q was used as initial value 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 the theoretical values with respect to the spectral type of each component. The q-search plot, the synthetic and observed light curves and the 3D model of AV CMi are shown in Figs 1-3, respectively, and the derived parameters from the light curve solution are listed in Table 1.

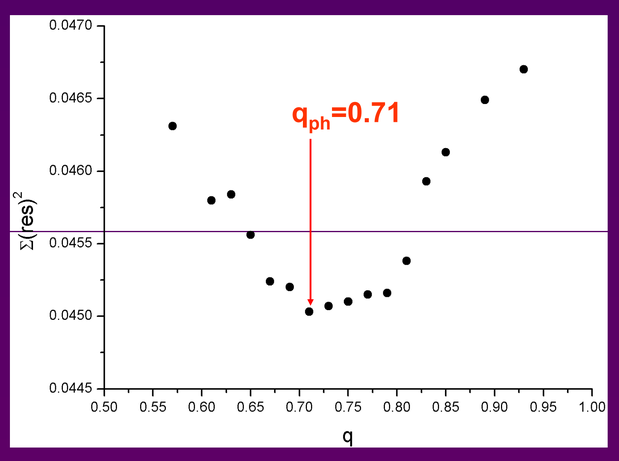

Fig. 1. The q-search plot of AV CMi.

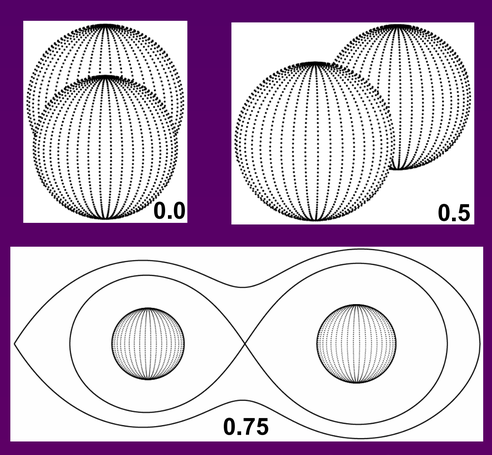

Fig. 2. The 3D model of AV CMi in various phases.

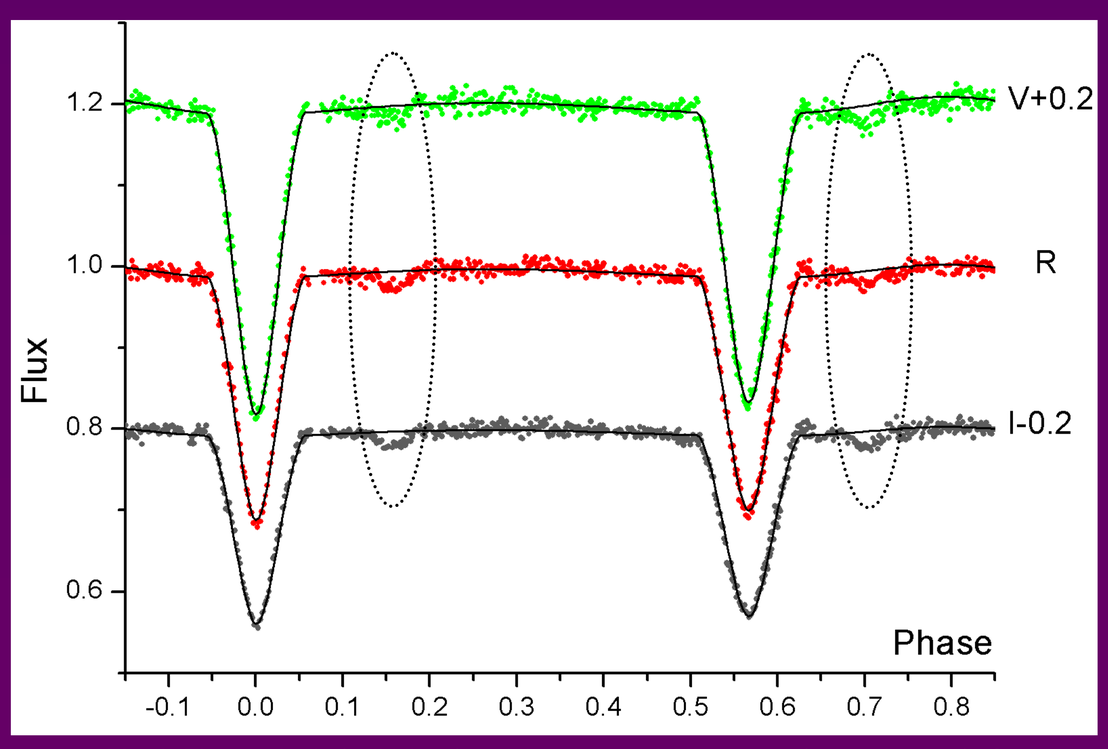

Fig. 3. The synthetic (solid lines) and the observed light curves (colored points) of AV CMi in V, R, I filters. The flux decrease indicated by the oval patterns are due to the transits of the third body in front of one of the components of the eclipsing pair.

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

Parameter	Value	Parameter	Value			
			V	R	I	
q	0.710 (2)	x_1**	0.493	0.418	0.345	
i (deg)	83.8 (4)	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	0.464 (1)	0.455 (1)	0.442 (1)	
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
e	0.11 (1)					
χ^2	0.08404					

**assumed, **taken from the tables of van Hamme (1993), $L_T = L_1 + L_2 + L_3$*

4. 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 was found in I filter, indicating that it is probably a cool body. The aim of the systematic observations of the triple system in I filter was the detection of many transits of the third body in front of one of the components of the eclipsing binary. We managed to detect five transits of the third body (see Fig. 4), to calculate its period and finally construct its light ephemeris, which is: ***T = HJD 2454521.36315 + 0.5192237^d × 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 2.6%.

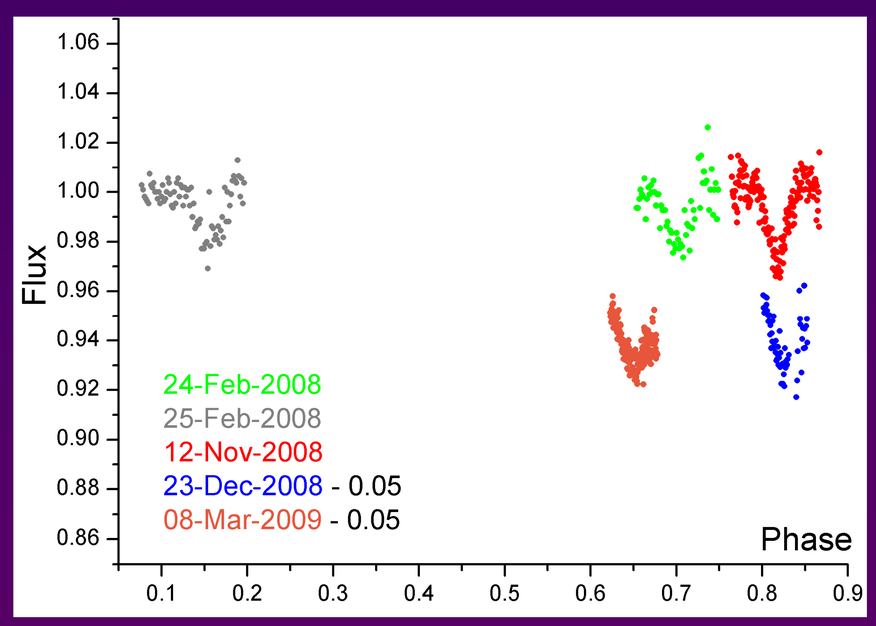

Fig. 4. The Flux drop of AV CMi in I-filter due to the transit of the third body in front of one of the other components. The colours of the symbols correspond to different dates of observations.

5. 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 contribution was found in I-filter, indicating its cool nature. Its period was found to be ~0.52^d, a value which shows that this body has an internal orbit, which is obviously almost coplanar with the one of the eclipsing pair. 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) define the mass ratio of the hot components, ii) reveal 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 its period with higher accuracy. To sum up, the preliminary results of the system 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.

6. Acknowledgements

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