We present new results from photometric study of an eclipsing object AV CMi. Liakos & Niarchos (2010) obtained preliminary parameters of the system in the form of magnitude measurements and discovered possible low-mass third body which they placed on an unusual inner orbit around the main of the stars. We confirmed in the light curve and analysed observable changes in the whole light curve. The third body system explanation was tested but new alternative – blend of two eclipsing binaries with period 1.898414 m is more realistic. Astrometric measurements of position of centroid unfortunately bring any information about their angular separation.

1 Introduction

AV CMi = 2MASS J07090841+1211090, an eclipsing system of Algol type, was discovered by Hoffmeister (1906). Subsequently Gezari (1974) determined provisional light-curve elements (variation between 11.8-12.2 mag (pg) and orbital period which is half of real one). This strong period was adopted by Svedinov & Kuznetsova (1990) to find the system absolute parameters from statistical dependencies between binary stars and their photometric light-curves, e.g. incorrect spectral types (F0) (G2V).

The system was for a long time practically neglected. First detailed analysis of photometric changes was made by Liakos & Niarchos (2010) and their results were updated Liakos, Mislis & Niarchos (2011) and two eclipsing pairs blended in one object on the sky (case 2). Both of cases are still unknown between known eclipsing systems and for this reason two procedures were written. Main ideas were adopted from Czagi & Pejcha (2012) and Lehmann et al. (2012).

3 Light curve analysis

We verified existence of the transit effect in the light curve and tried to determine host star in a situation when transit and eclipse take the same place, but without success (Liakas et al. 2012). Our contemporary aim is testing of two possibilities – binary with third body orbiting one of the main components (case 1A, 1B) same as (Liakos, Mislis & Niarchos 2011) and two eclipsing pairs blended in one object on the sky (case 2). Both of cases are still unknown between known eclipsing systems and for this reason two procedures were written. Main ideas were adopted from Czagi & Pejcha (2012) and Lehmann et al. (2012).

3.1 Case 1A, 1B – three body system

Variation of the total brightness m in time t for case 1A respective 1B is modelled as a sum of individual fluxes (F0, F1, F2) for all of three components. Their properties and orbital movement were described by parameters included in vector a as parameter included in vector a.

The third body (low mass) is placed in an circular orbit with a center in the host star – primary component (case 1A) respective in secondary one (case 1B). Covering of both stars by third body is allowed in this algorithm. All of the bodies are compact on projection (parameters a on 2D circular sphere) and have not equipotential surface but linear limb darkening is included. This approximation should be sufficient for our purpose.

Finding correct parameters for the models is a necessary part of calculation. We used gradient-development algorism (Marcaflip 1961, Dwyer 1992) based on nonlinear least-square method for minimization processes and Monte Carlo method for generation a lot of possible input parameters. After we chose the median parameters (the most probable value) as the best result.

4 Discussions and conclusions

We introduced two possible explanations of observed variations in the light curve – a mutual eclipsing triple system or two eclipsing pairs and we presented results of our modelling. First of them includes presence of the low-mass third body component or bright dwarf component in a three body system (case B). The third component is placed in a inner orbit around primary or secondary star (due to low value of period P3 ∼ 0.52d) and object has to orbit relatively between both of the main stars. This orbit path looks unusual and can be strongly unstable. We suppose that tides force caused by host star plays large role. When we adopted results from Liakos, Mislis & Niarchos (2011) Mr3 = 1.9 M⊙, a3 = 0.065 AU, MA = 1.65 M⊙, a1 = 0.015 AU) the Lagrange point L3 for system star (third body, case A) or third body system (case B) lies under the surface of the third body (for exoplanet) or just above (known dwarf).

A high amplitude of transit, which is more than most of a known transiting exoplanets, is also problematic point. Only three transiting exoplanets cause amplitude of transit more than 0.03 mag (WASP-10 0.10 mag, Qaatar-2 0.037 mag, CoRoT-2 0.032 mag). Furthermore observation of transit of known transiting exoplanet which would be observed in the system with isolated star and exoplanet. When we take into account brown dwarf as a creator of transits then high amplitude of transit is a must for exoplanet in host star. For these reasons we adopt this explanation as less realistic than second one.

Idea of two eclipsing systems (A and B) the same situation as e.g. V994 Her (Lee et al. 2008), Cha/V441 (Czagi & Pejcha 2012) brings more realistic explanation. Depositions in the light curve are better described by eclipsing system because their shapes are two pointed in “mid-transits”. We also noted that amplitudes of dips in the light curve are different between primary and secondary minimum of the system and we used and modelled eclipses for system B from Liakos, Mislis & Niarchos (2011) Ttrans = HJD2454895.873 ± 1.0384 d ± 4. The different amplitudes of primary and secondary eclipses of the system B is visible also in measurements of Liakos, Mislis & Niarchos (2011). Independent eclipses of the binary B also explained why it is possible observed “transit” in primary and also in secondary eclipses (Liakos et al. 2012) and dependence amplitude of “transit” to a wavelength.

Explanation by two binary pairs does not require strictly gravitational boundary of both systems. The two eclipsing systems could be projected on the same position in the sky. This alternative was tested by astrometric measurements of the AV CMi and shifted slits in the position of the centroid on the frames during main eclipses was not observed (Liakos et al. 2012). We supply that used main instrument has quite short focal length (f ∼ 2 m) and chance for detection was low, angular resolution 0.7 pixel and observed variation around central position was 0.1 pixel. Nevertheless a new photometric and especially spectroscopic observations are necessary.

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Our CCD photometric measurements in bands B, V, R, I were obtained on different observation sites but most of them was observed in Maunakea (Hawaii), St. John (MTP) and Armagh (UK). Photometric measurements of position of centroid on CCD ST-8 Mag. All reduction steps and differential aperture photometry were done by software C-Munipack ver. 1.1.28 (Motl 2009) based on DAOPHOT by Stetson (1987). CCD frames were standard calibrated (appropriate dark frames, flat fields). AV CMi was compared with stars GSC 770-911 (comparison star) and GSC 770-911 (check star) that were chosen as stars with good ratios S/N and with similar color for suppression of extinction. A lot of observations were systematic orbital for circular phase binary around primary star and primary eclipses and simultaneous phase close to mid-transits. This set-up was planned to capture situation when transit would not come or would be deformed by hiding covering non-host star.

3.2 Case 2 – two eclipsing binary systems

Total brightness in case 2 can be calculated similarly, an independence of both eclipsing systems is expected (any mutual orbit and eclipses). Total brightness is dependent on a sum of fluxes for system A as B (PA, PB).

Vectors a1, a2 contain parameters described individual objects and their orbits in each system. There was included parameter β in the model which masked ratio of fluxes between system A and B (Czagi & Pejcha 2012).