Determining the structure and properties of the triple system AV CMi

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ABSTRACT

In this work, we investigated the existence of a possible companion in the eclipsing binary system AV CMi, inspired by the detection of out-of eclipse transits. We analyzed the largest so far number of photometric observations of the system, acquired over a period of two years. Due to the Large depth of the transit, this candidate companion is possibly a brown dwarf or a more massive sub-stellar component. The orbit is of satellite type (S) with a period of 0.5 days around one of the two stars and according to the observations, it presents a high mutual inclination between 8 and 30 degrees depending on which the host star is. In total, our analysis aims in determining whether a third body actually exists and if it does, which star would be the host according to the data. In this sense, we first study the dynamical stability of the orbit. Following, we present a statistical test in order to disentangle between the two cases of the host star. finally, we propose a method to directly confirm the existence of this companion, through observation of it's transits in front of the non-host star, which causes significant non-periodic distortions in the total light-curve.

Observations and modeling

Our systematic observations of the AV CMi system are consistent with a flux drop of about 35 mmag, indicating a possible sub-stellar companion to the binary. The period of the transits is 0.5 days, allowing us to assume an S-type orbit with an average distance extremely close to the host star. Since we do not know which star is the host, we used two different models. In model A, the third body orbits the primary component of the binary, while in model B, the secondary component is considered as the host star. The diversity lies in the fact that the fractional luminosity contribution of the star that is not eclipsed is different. We used 4 transit light-curves and 10 observations around the minima of the eclipsing binary in order to constraint the initial conditions required for a simulation of the dynamics of the system . The light-curves around the minima were obtained by a team of amateur astronomers in Greece.

Dynamical properties and stability

We integrated Newton's equations of motion in the general case of non co-planar orbits using the Velocity Verlet integrator which is symplectic. However the very short period of the third body (0.5d) imposes a very smalltime step for the integration and so a full dynamical stability test for this system (Gy timescales), would require at least one month. Our simulations show that the orbit is stable for both cases on the ky timescale. However in this work we only present the osculating inclination and eccentricity of the orbit and explain how the first can be used in order to achieve an indirect confirmation of a third companion. In figures 2 and 4 it is obvious that the inclination variation is so large that would cause significant depth variations in the transit light-curve easily observed with amateur equipment. In the future we plan to collect as many transit light-curves as we can in order to validate this behaviour.

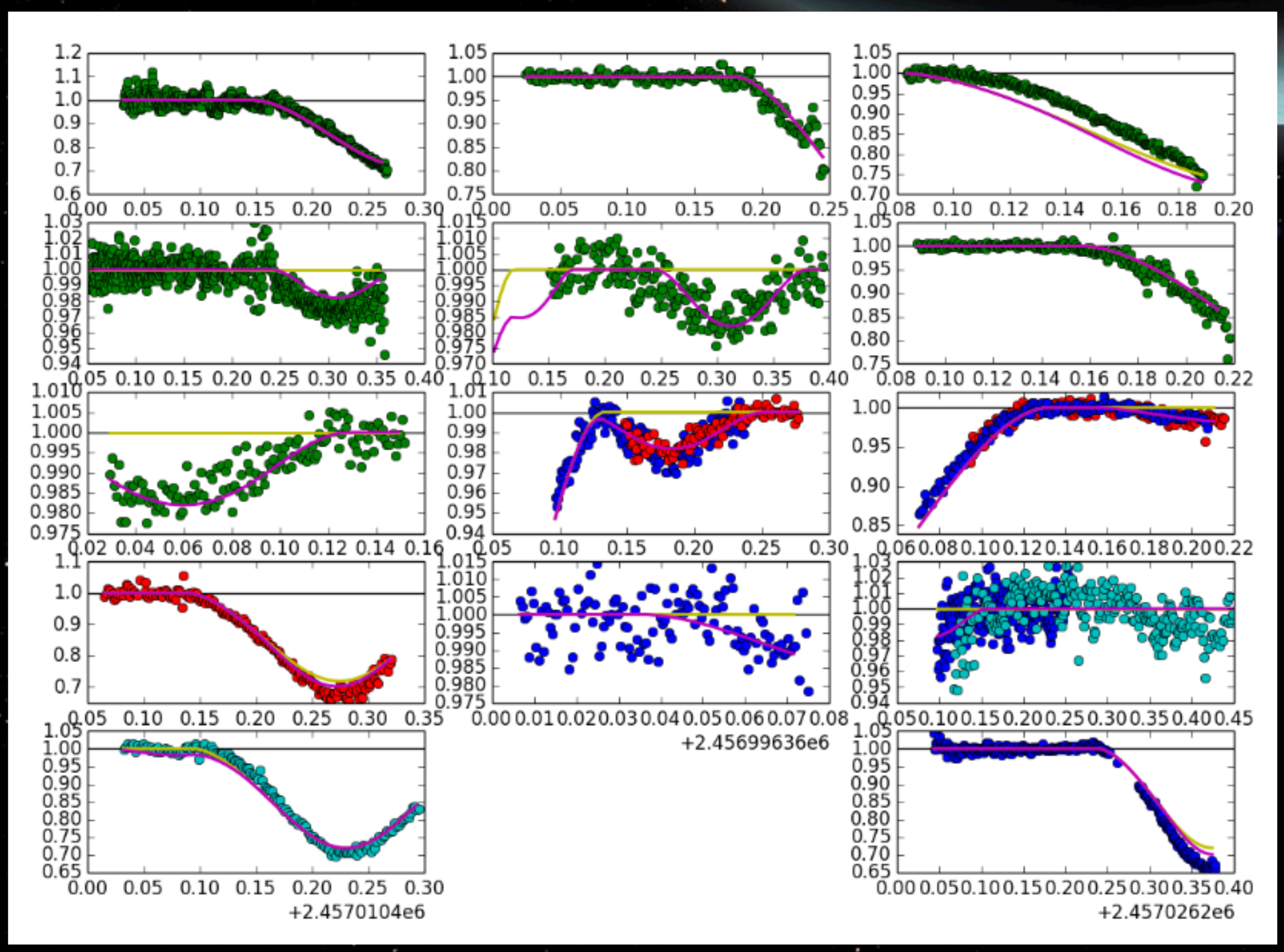

Figure 1: All of the observations obtained from the Holomon Astronomical Station (green), and by K. Emmanouilidis (red), E. Kardasis (blue), and I. Strikis (cyan).

Orbital elements	Third body, case A	Third body, case B	Other star
I [deg.]	51.8	72.2	83.8
ω [deg.]	0.0	0.0	210
Ω [deg.]	0	0	0
e	0	0	0.11
f [deg.]	π/2	π/2	0
P [days]	0.5	0.5	2.27

Table 1: Initial conditions for cases A and B obtained from the light-curve analysis

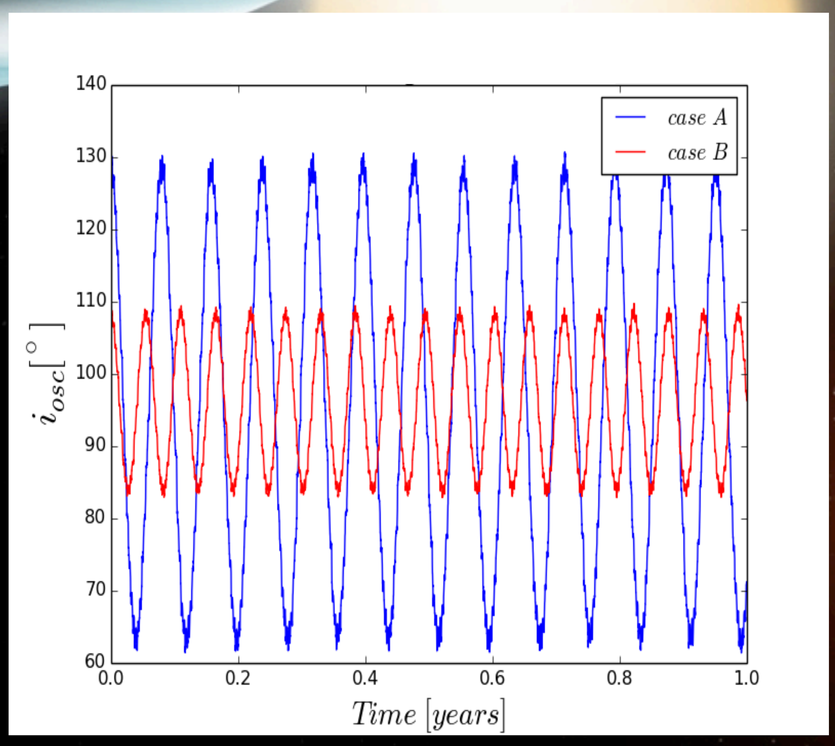

Figure 2: Osculating inclination.

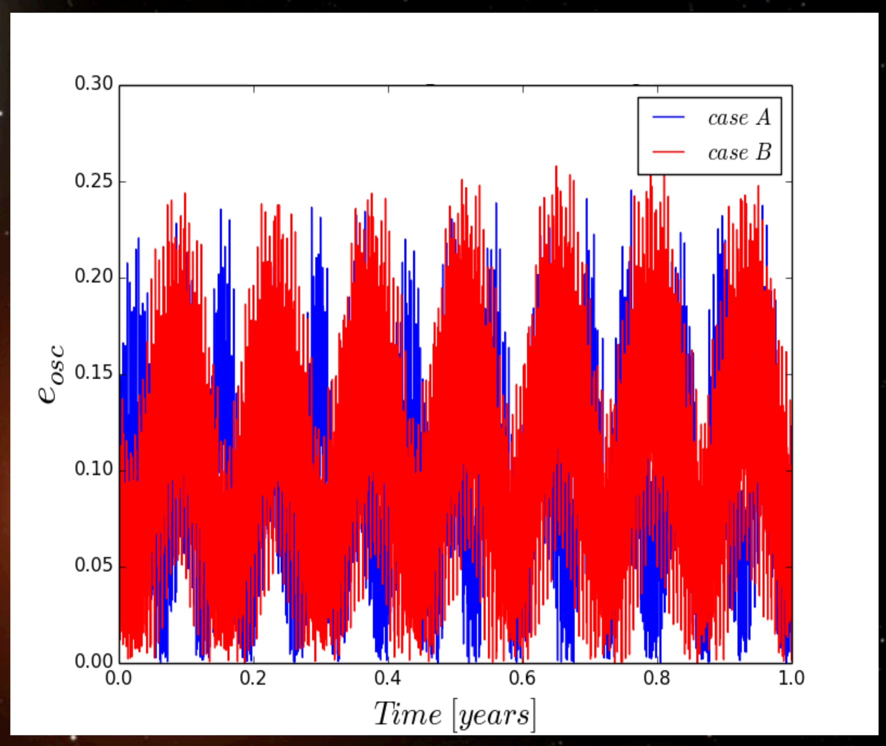

Figure 3: Osculating eccentricity.

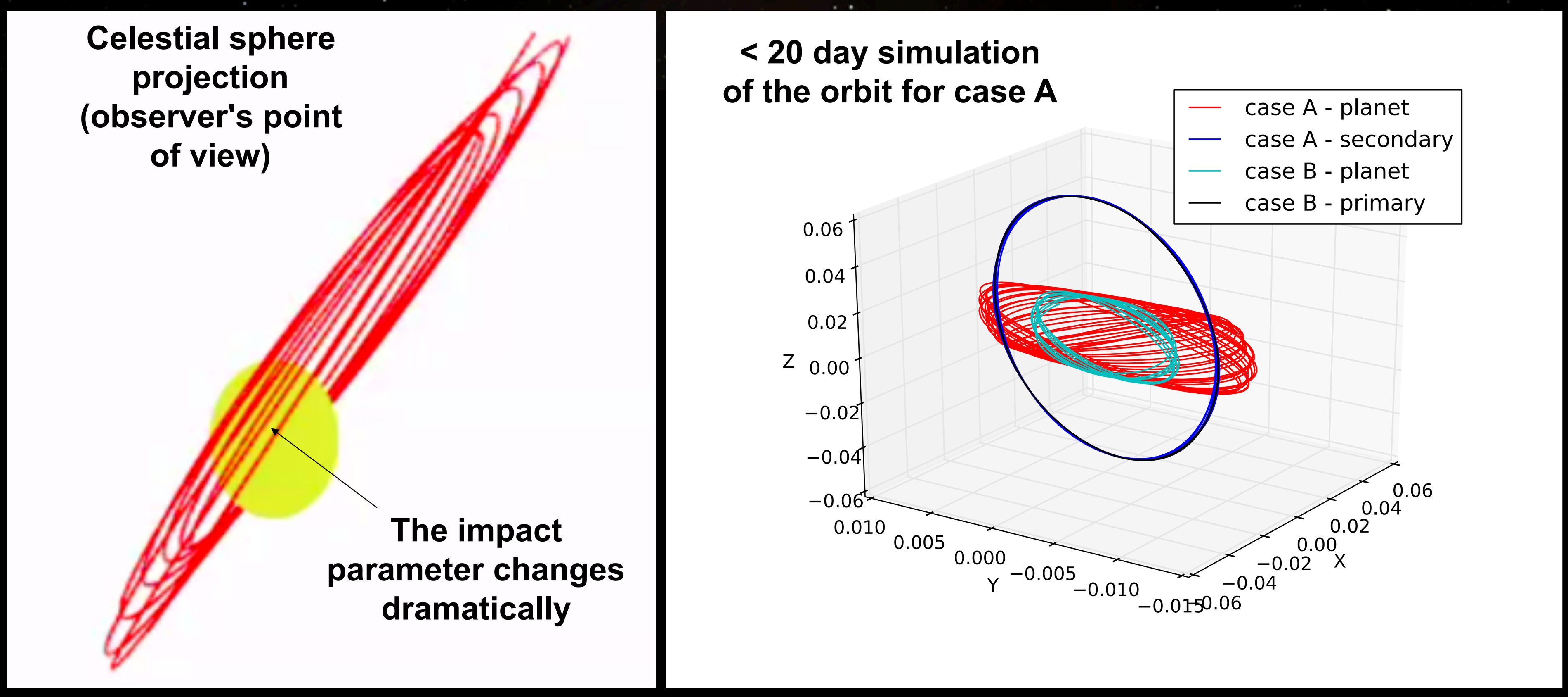

Figure 4: 3D representation of the third body's orbit.

References

[1] A.Liakos, D.Mislis, P.Niarchos,"The Third Body in the Eclipsing Binary AV CMi: Hot Jupiter or Brown Dwarf?" , IAU Symposium, Volume 282, p. 57-58

[2]Liška, J. et. al., "The New Photometric Study of a Possible Three-body System AV Cmi", Central European Astrophysical Bulletin, Vol. 37, p. 201-206