PERIODICITY AND ECLIPSE MINIMA TIMING OF CM DRACONIS

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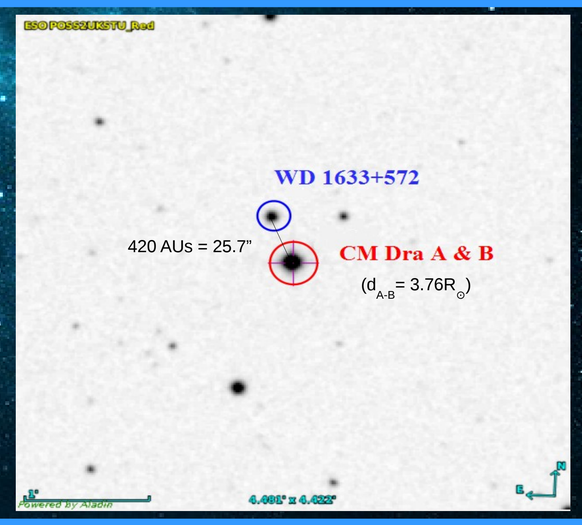
ABSTRACT

Periodic deviations from a linear ephemeris of a binary star's eclipses can indicate the presence of a third body in orbit around both components. Hints for such a hypothetical companion around the M4.5/M4.5 binary CM Dra were published by Deeg et al. (2000) and Deeg et al. (2008). The assignment of a planet in the CM Dra system can however only be accepted if the earlier observed periodicity trends can be verified through further observations over several years. For eclipsing binary stars of low mass, the method of eclipse minimum timing allows one to set mass limits for the detection of a third body. Deeg et al. (2008) concluded that the two possibilities for the source of CM Dra's timing variations that remain valid are a planet of a few Jupiter masses on a two decade-long orbit, or an object on a century-to-millenium long orbit with masses $1.5M_J < M_{perturber} < 0.1M_\odot$. However, they concluded that it is necessary to do continued observations of the timing of CM Dra's eclipses to be decisive regarding the continued viability of the sinusoidal-fit-model, and hence, about the validity of a Jovian-type planet in a circumbinary orbiting around the CM Dra system. In this work, we update the analysis of Deeg et al. (2008), including further data presented in Morales et al. (2009) and new observations taken at Ural Observatory, Russia, during 2008-2013. Eclipse minimum times of all new observations were obtained using the Kwee-van-Woerden method.

CM DRACONIS

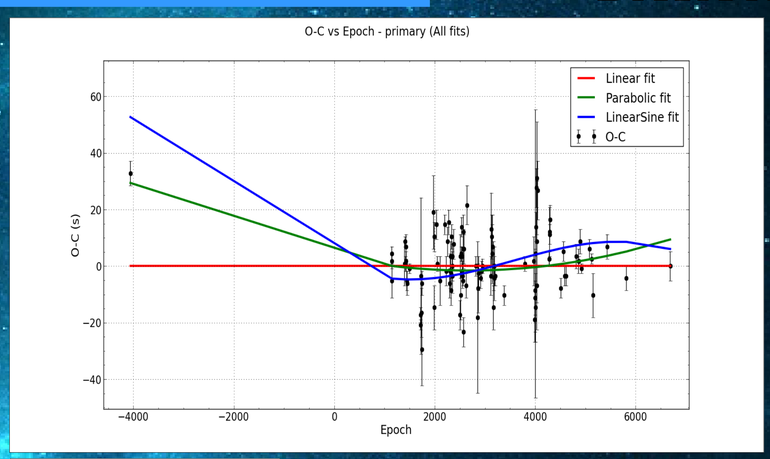
CM Draconis (GJ 630.1A, $\alpha_{J2000.0}$=16h 34m 20.35s, $\delta_{J2000.0}$=+57° 09' 44.7") is an eclipsing binary system of magnitude V=12.9 which forms a common proper motion pair with a white dwarf (WD 1633+572) with magnitude V=15 (GJ 630.1B, $\alpha_{J2000.0}$=16h 34m 21.57s, $\delta_{J2000.0}$=+57° 10' 09.0") at a separation of ~26 arcsec. This system has one of the lowest known total mass of $0.44M_\odot$, at a distance of 14.5pc in the Draco constellation. The system consists of two almost identical M4.5 red dwarfs orbiting each other with a period of ~1.27 days. With its nearly edge-on inclination of 89.59° it was chosen as the target of the first photometric search for planetary transits in the mid 1990's.

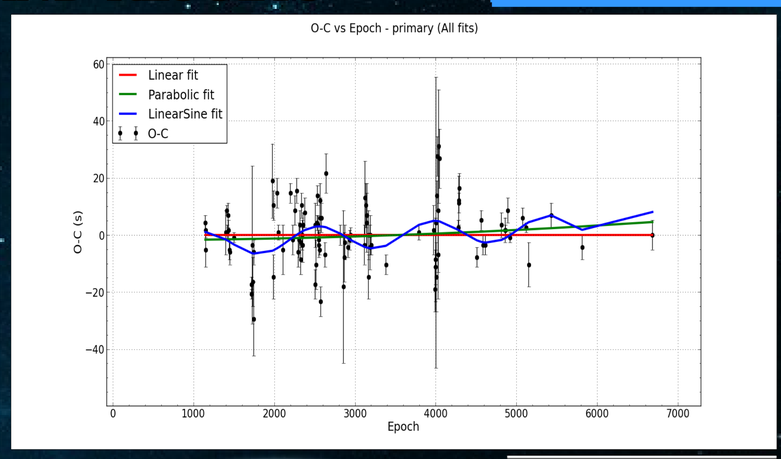


ANALYSIS PERFORMED ON O-C DIAGRAM

* New linear ephemeris derived
*Fits against O-C times: linear, parabolic, linear+sinusoidal
* MCMC method
* χ^2 (chi-square)
* BIC
* Periodogram
* Apsidal motion

DATA AND RESULTS

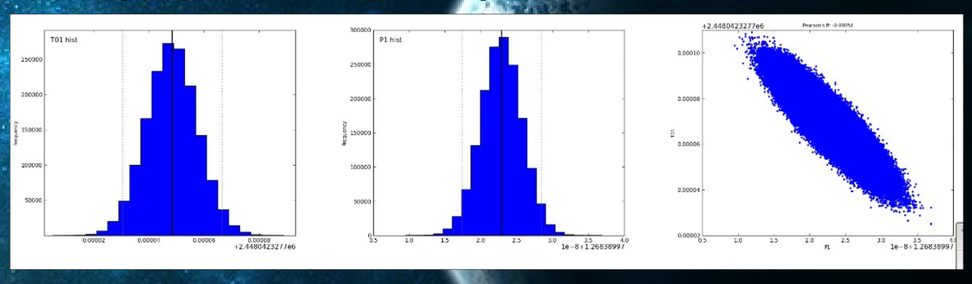




	ε_{orig}
Fit	BIC
Linear	567
Linear	378
Parabolic	507
Parabolic	317
Linear+sine	503
Linear+sine	317

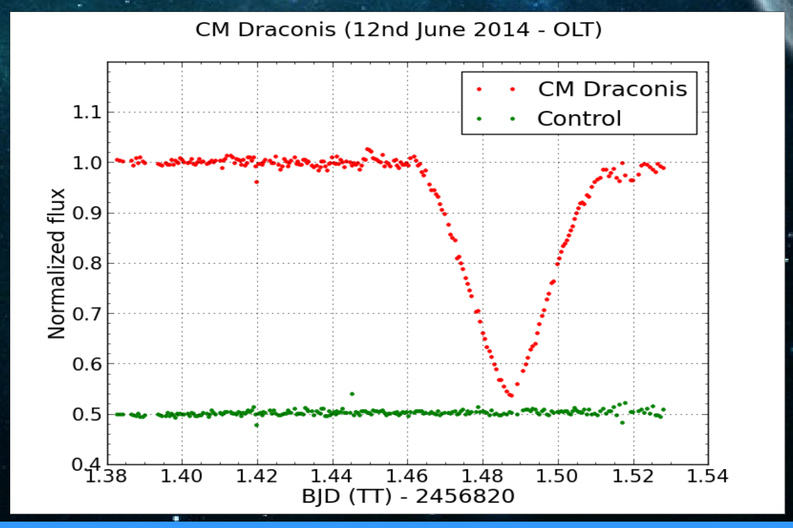
Table 1: BIC values of primary (first lines) and secondary (second lines) eclipses of the linear, parabolic and linear+sinusoidal fits.

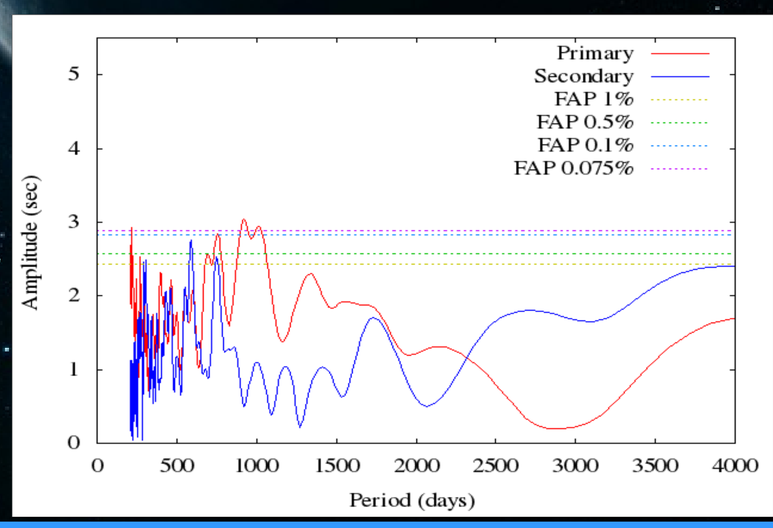
* *Up (left to right):* Linear, parabolic and linear+sinusoidal fits for primary eclipses taking into account the early data from Lacy (1977) and not taking them into account.
* *Center (left to right):* Histograms of T_0 and P. Scatter diagram of the MCMC parameter values.
* *Bottom (left to right):* The full light curve of CM Dra using the 1.2m Oskar-Lühning-Teleskop (OLT) in Germany. A Lomb-Scargle periodogram from O-C residuals versus the linear ephemeris of the CM Dra system for primary (red) and secondary (blue) eclipses.



	ε_{orig}
Fit	BIC
Linear	497
Linear	317
Parabolic	501
Parabolic	315
Linear+sine	448
Linear+sine	329

Table 2: Without the early data from Lacy (1977). BIC values of primary (first lines) and secondary (second lines) eclipses of the linear, parabolic and linear+sinusoidal fits.





CONCLUSIONS

* Data are best fitted by a parabolic or a linear+sinusoidal fit.

* No indications for non-linear O-C times when omitting early data from Lacy (1977).

* For now, we can not verify the validity of a Jovian-type planet in a circumbinary orbit around the CM Dra system, so it will be necessary to continue with minimum time observations of CM Dra's eclipses.

BIBLIOGRAPHY: Deeg et al. (2000), Deeg et al. (2008), Lacy (1977) and Morales et al. (2009).