ECLIPSING BINARIES IN MULTIPLE SYSTEMS

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ABSTRACT : *To undertake dynamical studies on stellar triple systems and to test stellar models for subsolar mass stars, a photometric and spectroscopic observational campaign of newly discovered HIPPARCOS eclipsing binaries has been realized since 1997 through a collaborative international effort. Starting with a sample of 50 candidate objects, we retained at the end 36 systems, from which 24 are new double-lined eclipsing binaries. We found seven objects to be new spectroscopic triple systems and confirmed the presence of the spectroscopically visible third body in three other systems." Two triple systems, CU Cam and CN Lyn present evident long-period variations of the third body radial velocity as well as changes of the center-of mass velocity of eclipsing system. We present and discuss the results of the photometric and spectroscopic data for these two triple systems.*

I. New photometric and spectroscopic observations of HIPPARCOS eclipsing binaries

In 1997, we started an international large-scale project with a goal of obtaining complementary ground-based photometric and spectroscopic information on new detached eclipsing binaries, discovered during the HIPPARCOS mission.

Two astrophysical applications were considered in the choice of the programme stars : the study of the dynamical effects of the orbital parameters in the eclipsing binaries due to a third companion, and the tests of theoretical evolutionary models for stars with sub-solar masses in function of internal structure parameters, for example, the convection value.

The selection of the programme stars is based on the following criteria:

1. All the chosen eclipsing binaries are newly discovered by HIPPARCOS
2. The periods of the systems are mainly longer than one day
3. The detached eclipsing binaries are mainly of F, G or K spectral types
4. The systems had no known radial velocity measurements

The radial velocity measurements were carried out, from 1997 to 2005, at the Haute-Provence Observatory, France, with CORAVEL and ELODIE spectrographes. We have begun parallel photometric observations at various observatories : Cracow, Poland, Krioneri, Greece, and, more recently, Lvov, Ukraine and AUG and TUG, Turkey.

We present here the results of the radial velocity detection of ten triple systems, in particular, two interesting objects : CU Cam and CN Lyn.

III. Eclipsing binaries CN Lyn and CU Cam as members of triple systems

Two systems, CN Lyn and CU Cam, clearly show time variations of the movement of its center-of-mass and third bodies radial velocities.

Two orbital solutions for each system is presented in Figure 1 and in Table 2.

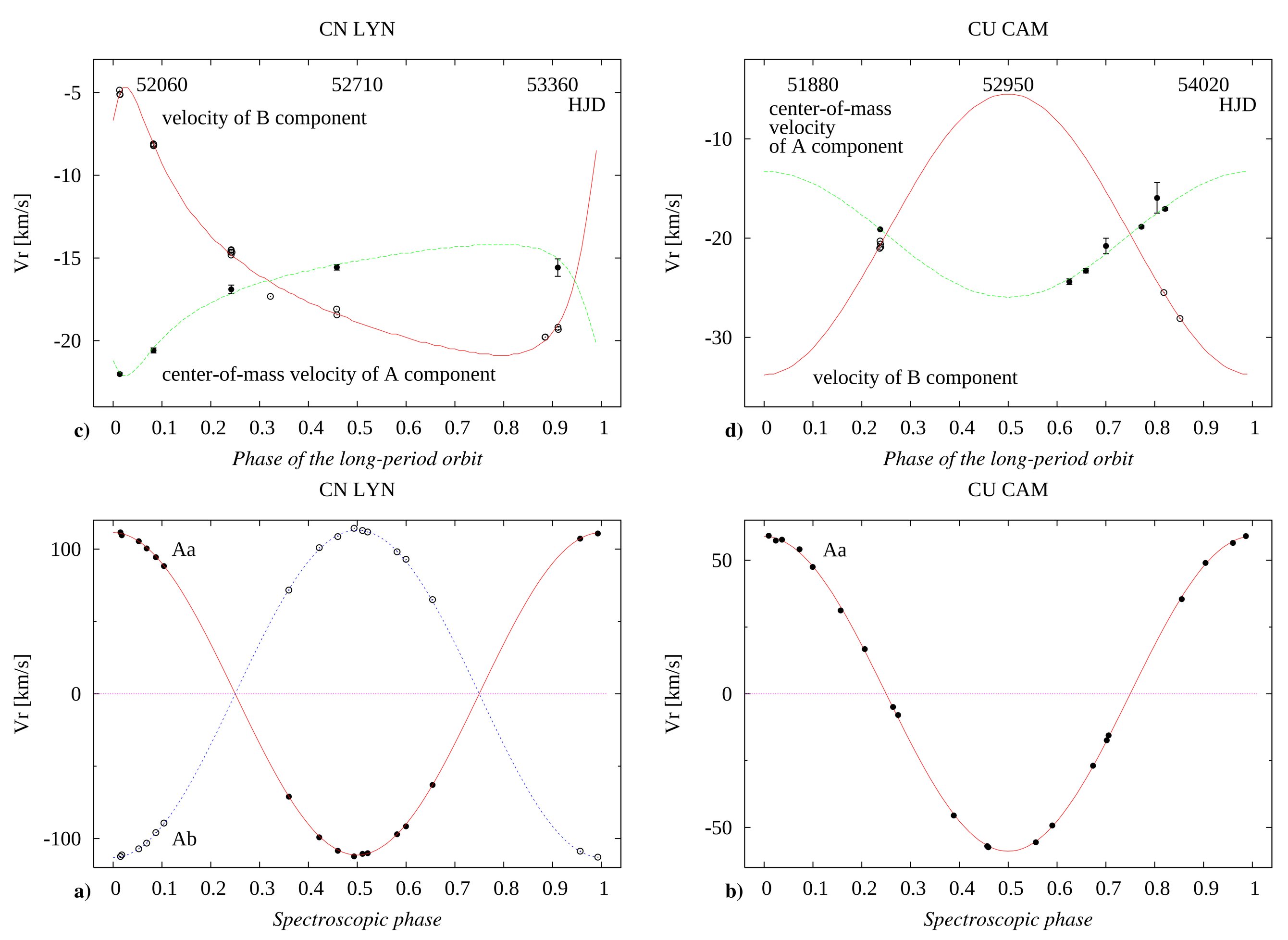

Fig. 1. Bottom part : Radial velocity curves for CN Lyn – a) and CU Cam – b) in the rest coordinate system. Upper part: Radial velocity curves for wides system : in case of CN Lyn –c), and CU Cam –d)

Table 2 : Orbital elements of CU Cam and CN Lyn systems.

Name	Comp	P	T_0(JD)	e	ω	V_0	K	q/f(m)	asini	$M\sin^3 i$	σ
		days	+2450000		^{o}	km s^{-1}	km s^{-1}	$M_\odot$	Gm	$M_\odot$	km s^{-1}
CU Cam long-period orbit											
	A	2478	1711	0.0	-	-19.62	6.33	0.45	216	1.52	0.89
		±39	±30				±.26	±.07	±14	±.35	
	B						14.14		482	0.68	0.58
							±1.9		±64	±.14	
CU Cam short-period orbit											
	Aa	3.363767	2820.770	0.0	-	var	59.08	0.0719	2.733		0.53
		-	±.002				±.17	±.0006	±.008		
CN Lyn long-period orbit											
	A	1625	1908	0.59	318.8	-16.38	3.98	0.491	71.57	0.10	-
		±35	±13	±.04	±2.5	±.08	±.17	±0.10	±4.3	±.01	
	B						8.10		146	0.051	0.29
							±.19		±7	±.005	
CN Lyn short-period orbit											
	Aa	1.955505	2308.110	0.0	-	var	111.40	0.985	2.996	1.155	0.78
		±.000006	±.001				±.21	±.003	±.006	±.004	
	Ab						113.12		3.042	1.138	0.90
							±.21		±.006	±.004	

II. Eclipsing binaries with a third companion

For ten eclipsing binaries (Table 1), we established, from the spectral lines, the presence of a third body for which we measured the velocity.

Five of them (HR UMa, CX CVn, EM Boo, MR Del and V2154 Cyg) have close companion, described for the first time in the HIPPPARCOS Catalogue (ESA, 1997).

For CU Cam, the HIPPARCOS DMSA gives a G-acceleration solution.

V453 Cep is only one object from Table 1 with known radial velocity curve of the third body (Griffin, 1990) but we learn about it being near to end of our VR observations. More details can be find in part III and IV of this poster.

Tabe 1 : HIPPARCOS eclipsing binaries with a third companion

Name	HIP	V	B-V	SpT	Var	P	Rem	N_{RV} C	N_{RV} E	Comp 1	Comp 2	Comp 3	Phot
CU Cam	17333	7.88	0.118	A0	EA	3.363767(4)	A	12	4	1		1	C(o)
V1149 Tau	21621	8.45	0.223	A0	EA	4.9074	?		1			1	
CF Lyn	37748	9.54	0.532	F8	EA	1.38536(3)	A		10	1	1	1	L(o)
CN Lyn*	39250	9.01	0.413	F5	EA	1.955505(6)	A		17	1	1	1	C(f),L(f)
HR UMa	56330	8.70	0.425	F8	EA	1.474129(5)	C		16	1	1	1	C(f)
CX CVn	68384	9.32	0.574	F8	EA	3.281602	C	8	8	1		1	C(o),L(o)
EM Boo	72426	9.02	0.506	G5	EA	2.44616(4)	A		14	1	1	1	C,K
MR Del	101236	8.77	0.696	K0	EA	0.521690	?	8	9	1	1	1	K
V2154 Cyg	105584	7.78	0.441	F0	EA	2.630641(6)	A	8	13	1	1	1	C,T(o)
V453 Cep*	112972	7.42	0.590	A0+	EA	1.18475(2)		4	18			1	C(f)

NOTES:

1. An asterisk after the name means that the solutions of radial velocity curves were published after 1997 by other authors.
2. Column Rem : modification of P_{HIP} based on our observations : C - the period is significantly corrected; A - the period is slightly corrected; ? - on the grounds of our observations, the period cannot be updated. The modified period are followed by the (errors).
3. N_{RV} - Number of CORAVEL (C) and/or ELODIE (E) radial velocity measurements.
4. Comp - information about the detected component in the system.
5. Phot - Present status of the photometric observations carried out in Cracow (C), Lvov (L), Krioneri (K) or at Turkish observatories (T), with (f) for the finished and (o) for the ongoing observations.

IV. Discussion

For CU Cam and CN Lyn, we had observed well narrow dips for the third body, giving variations of the RV in time.

We applied the following general reduction procedure :

first, we determined the period using all observations without considering the gamma effect,

secondly, for each observational mission we determined gamma and orbital elements using the "FOTEL" Hadrava's programme.

Gamma and radial velocities for the systems and for the third body are presented on the Figure 1.

CN Lyn system :

Marrese et al. (2004) carried out spectral observations of this system. They signalized the presence of a third body, visible in the spectra, but they did not analyse its radial velocity in function of time. They concluded that the third companion should be a similar star as the components of the eclipsing system.

From the low values of $M\sin^3 i$ in the table 2 for the companion, we should conclude that the inclination of its orbit is far from 90. That means that he has a mass comparable to the mass of the components (taken into account the ratio equal to 0.5 between the mass of the third body and the eclipsing binary one).

CU Cam system :

The ELODIE dips of the radial velocity for the third body remained constant during four nights 2002, but changed in January and February 2006. The Hipparcos gravitational solution mentionnes a significant G-acceleration solution for this system. It means that CU Cam has a faint companion not seen by the satellite or too closed to be resolved.

References

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