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**THE FIRST GROUND-BASED PHOTOMETRY  
OF CONTACT BINARIES FN Cam AND EX Leo**

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FN Cam (HD 46005, HIP 79886, 9<sup>h</sup>22<sup>m</sup>58<sup>s</sup>.0, +77°13'10''9, 2000.0,  $V_{max} = 8^m58$ ,  $V_{min} = 9^m05$ ) is one of the systems discovered by the Hipparcos mission (ESA, 1997). In the Hipparcos catalogue it is classified as a contact binary of F2 spectral type with the following ephemeris for the primary minimum:

$$\text{Min I} = 2\,448\,500.427 + 0.677128 \times E. \quad (1)$$

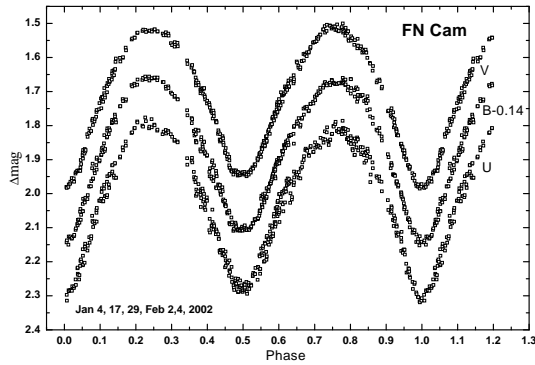
EX Leo (HD 93077, HIP 52580, 10<sup>h</sup>45<sup>m</sup>06<sup>s</sup>.8, +16°20'15''7, 2000.0,  $V_{max} = 8^m27$ ,  $V_{min} = 8^m49$ ) is another system discovered by Hipparcos and classified as a  $\beta$  Lyrae variable of F5 spectral type with the following ephemeris for the primary minimum:

$$\text{Min I} = 2\,448\,500.008 + 0.408604 \times E. \quad (2)$$

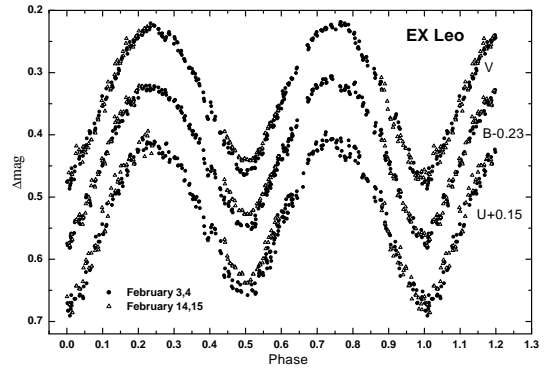
Both systems were observed spectroscopically. For FN Cam Rucinski et al. (2001), determined  $q = K_1/K_2 = 0.222 \pm 0.005$  and  $(m_1 + m_2) \sin^3 i = 2.496 \pm 0.069 M_\odot$  and gave two estimates of the spectral type: A9 and F2. For EX Leo Lu et al. (2001) determined  $q = 0.199 \pm 0.004$  and  $(m_1 + m_2) \sin^3 i = 1.255 \pm 0.036 M_\odot$  and F6V spectral type. Both

Table 1: New times of the primary (I) and secondary (II) minima. The standard errors of the minima are given in parentheses. The (O-C) residuals are given with respect to the Hipparcos ephemerides

	JD <sub>hel</sub> 2 400 000+	type	(O – C)
FN Cam	52292.3670(5)	I	0.0232
	52304.5563(2)	I	0.0242
	52307.2611(7)	I	0.0205
	52310.3107(3)	II	0.0230
EX Leo	52309.6134(5)	II	–0.0140
	52320.4419(1)	I	–0.0135
	52321.4647(2)	II	–0.0122



**Figure 1.** The *UBV* light curves of FN Cam relative to HD78846. The *UB* observations were shifted for clarity and phased according to ephemerides (3).



**Figure 2.** The *UBV* light curves of EX Leo relative to HD92511. The *UB* observations were shifted for clarity and phased according to ephemerides (4)

systems were classified as A-type contact binaries. Apart from the Hipparcos photometry no photoelectric or CCD light curve of the systems has been published.

Photoelectric light curves were obtained at the Stará Lesná and Skalnaté Pleso observatories of the Astronomical Institute of the Slovak Academy of Sciences. FN Cam was observed during 6 nights on January 4, 17, 29 and February 1, 2, 4, 2002 and EX Leo during 4 nights February 3, 4, 14, 15, 2002. At both observatories 0.6-m Cassegrain telescopes equipped with a single-channel photoelectric photometer were used. The standard *UBV* filters were used for all observations. Data reduction, the atmospheric extinction correction and transformation to the standard *UBV* system were carried out in the usual way (see Pribulla et al., 2001). For all observations of FN Cam HD 78846 and HD 81282 were used as the comparison and check star, respectively. In case of EX Leo HD 92511 and HD 92648 were used. Both systems show small light-curve changes seen in the differences of maximum height of FN Cam and the changes of the secondary minimum of EX Leo (see Figure 1). All individual observations are available in file 5258-t3.txt and 5258-t4.txt

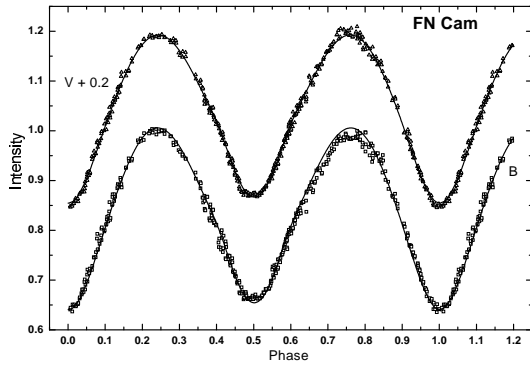
Four new minima times of FN Cam (Table 1) determined using Kwee & van Woerden method (weight  $w = 2$ ), together with Hipparcos  $JD_0$  ( $w = 1$ ) and time of the spectroscopic conjunction  $T_0 = 2451351.1554$  ( $w = 1$ ) determined by Rucinski et al. (2001) provide the new ephemeris:

$$\text{Min I} = \text{HJD } 2452292.3667 \pm 12 + 0.6771320 \pm 6 \times E, \quad (3)$$

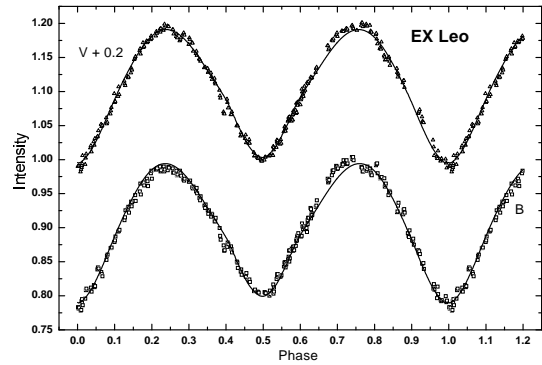
In the case of EX Leo our three minima augmented by the Hipparcos  $JD_0$  and the time of the spectroscopic conjunction  $T_0 = 2451615.6025$  (Lu et al., 2001) provide the following ephemeris:

$$\text{Min I} = \text{HJD } 2452309.4099 \pm 3 + 0.40860258 \pm 8 \times E. \quad (4)$$

The photometric elements were determined using the 1992 version of the Wilson & Devinney (1971) code. Due to a lower precision of the *U* observations only the *BV* data were used to determine the photometric elements. The mean temperature of the primaries



**Figure 3.** The best fits to the  $BV$  observations of FN Cam.



**Figure 4.** The best fits to the  $BV$  observations of EX Leo

Table 2: Photometric elements and their standard errors (given in parentheses). Fill-out is defined as  $F = \frac{\Omega_{inn} - \Omega}{\Omega_{inn} - \Omega_{out}}$ . Parameters not adjusted in the solution are denoted by a superscript “a”

Parameter	FN Cam	EX Leo
$i$ [°]	71.2(2)	61.1(1)
$q$	0.222 <sup>a</sup>	0.199 <sup>a</sup>
$\Omega$	2.162(2)	2.190(2)
Fill-out	0.88(2)	0.31(2)
$T_1$ [K]	6700 <sup>a</sup>	6330 <sup>a</sup>
$T_2$ [K]	6848(11)	6167(13)
$L_1^B / (L_1^B + L_2^B)$	0.754(1)	0.825(1)
$L_1^V / (L_1^V + L_2^V)$	0.760(1)	0.823(1)

of FN Cam and EX Leo were set according to F2V ( $T_1 = 6700$  K) and F6V ( $T_1 = 6330$  K) spectral types using the calibration of Popper (1980). The limb and gravity darkening coefficients as well as bolometric albedos were fixed appropriate to the convective envelope as usual for contact binaries. The resulting photometric parameters are given in Table 2 and the corresponding fits to the  $BV$  observations of FN Cam and EX Leo are shown in Figure 2. The errors reported in Table 2 are underestimated due to the applied modelling code.

For FN Cam we excluded observations in the  $B$  passband in the phase interval 0.6–0.9, where the light curve is depressed probably by the presence of spots. Although there seems to be an interval of constant light during the secondary minimum the system is certainly partially eclipsing. For  $q = 0.222$  and  $F = 0.88$  the total eclipses occur for inclinations  $i > 76^\circ.73$ . It is interesting to note that the O’Connell effect is of the opposite sign in the  $B$  and  $V$  passbands. That’s why the attempt to improve the fit by introducing a spot on either of the components failed. The inclination angle combined with the spectroscopic elements leads to the following masses of the components:  $m_1 = 2.40 \pm 0.06 M_\odot$  and  $m_2 = 0.53 \pm 0.02 M_\odot$ . It is interesting to note that the system is quite overmassive for its spectral classification.

Since the light curve of EX Leo seems to be variable, we analyzed only the observations performed on the first two nights with the full coverage of the light curve. The resulting masses of the components are:  $m_1 = 1.56 \pm 0.04 M_\odot$  and  $m_2 = 0.31 \pm 0.01 M_\odot$ .

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