Photometric study of the short period W UMa system – FZ Orionis

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Abstract

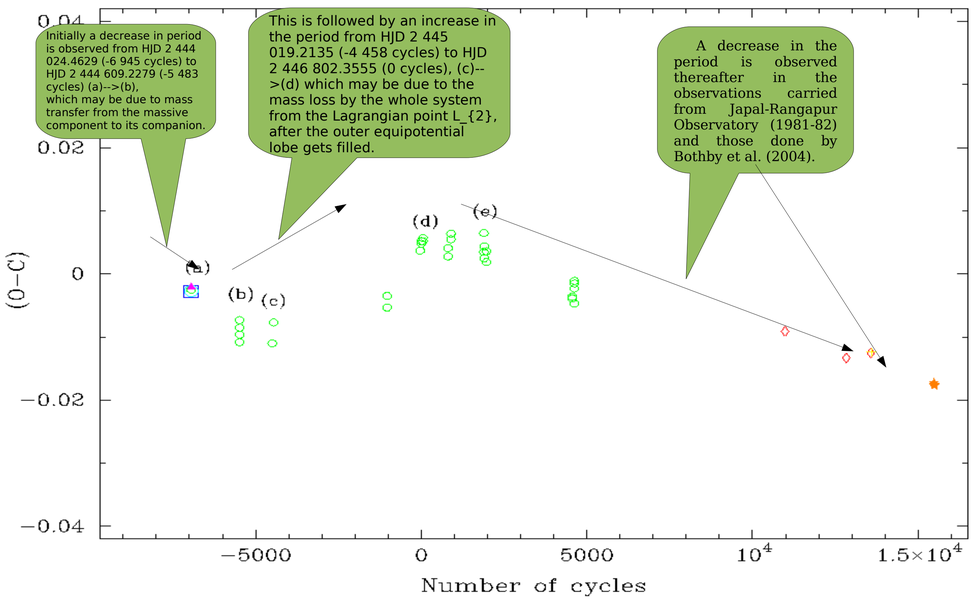
W Ursae Majoris (W UMa) variables are the most extreme examples of tidally distorted stars in contact binaries in which both components fills or overfills their inner Lagrangian zero-velocity surfaces, known as Roche lobes. One of the prototypes of W UMa variables - FZ Orionis is studied. Photoelectric B and V observations of this eclipsing binary system obtained from the Japal-Rangapur Observatory show period changes indicating cyclic process of mass transfer and mass loss from the system. The light curves are analyzed using the Wilson-Devinney method and the system parameters are derived. The evolutionary status of the system is discussed.

General information on FZ Orionis:

Right Ascension (1990): $05^h36^m08^s$
Declination (1990): $+02^o33'$.
Catalogue No.: HD 288 166
Visual magnitude = $9^m.44$; spectral type G0
Variability was discovered by Hoffmeiester (1934)
El-Bassuny derived system parameters through differential photometry:
- a period of $0^d.399873$
- system mass ratio 'q' = 0.2 to 0.6
- the fill out parameter 'f' = 0.5 to 1.0

The system was categorized as W-subtype contact binary

Period Analysis



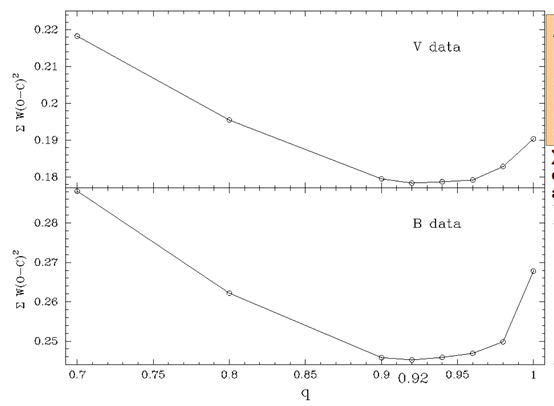
To determine the reliable elements and to understand the nature of this binary, it was included in the observational program of the Japal-Rangapur Observatory, Osmania University.
A total of 31 times of primary minima was obtained, using these along with other times of minima available in the literature, the improved ephemeris was obtained as:

MinI = HJD 2 446 802.3503±0.3 999 840 96E
±5 ±10

Light curve Analysis

Elements obtained from the solution of individual and combined VB light curves using Wilson-Devinney method for FZ Ori, keeping $T_{e,h}$=6030°K and q=0.92 as fixed parameters. (* Fixed parameters, + In units of total system at phase 0.25)

Element		V	B	Combined VB solution	El-Bassuny's solution
1		2	3	4	5
*$T_{e,h}K$		6030	6030	6030	~Spectral type
$T_{e,c}K$		5911	5803	5840 ± 47	G0
*q		0.92	0.92	0.92	0.2 to 0.6
i^o		68.63	69.13	68.81 ± 0.04	75 to 90
r_h	pole	0.3929	0.3929	0.3929 ± 0.0013	
	point	0.5000	0.5000	0.5000 ± 0.0014	
	side	0.3816	0.3816	0.3816 ± 0.0014	
	back	0.4122	0.4122	0.4122 ± 0.0015	
	back	0.4122	0.4122	0.4122 ± 0.0015	
r_c	pole	0.3490	0.3490	0.3490 ± 0.0020	
	point	0.4828	0.4828	0.4828 ± 0.0020	
	side	0.3662	0.3662	0.3662 ± 0.0019	
	back	0.3973	0.3973	0.3973 ± 0.0020	
L_h		0.5406	0.5457	V 0.5299 ± 0.0007 B 0.5570 ± 0.0008	
L_c		0.4594	0.4543	V 0.4701 B 0.4430	
+L_3		0.0	0.0	V 0.0 B 0.0	
x_h		0.60	0.60	V 0.60 B 0.60	
x_c		0.60	0.60	V 0.60 B 0.60	
*A_h		0.5	0.5	0.5	
*A_c		0.5	0.5	0.5	
*G_h		0.32	0.32	0.32	
*G_c		0.32	0.32	0.32	

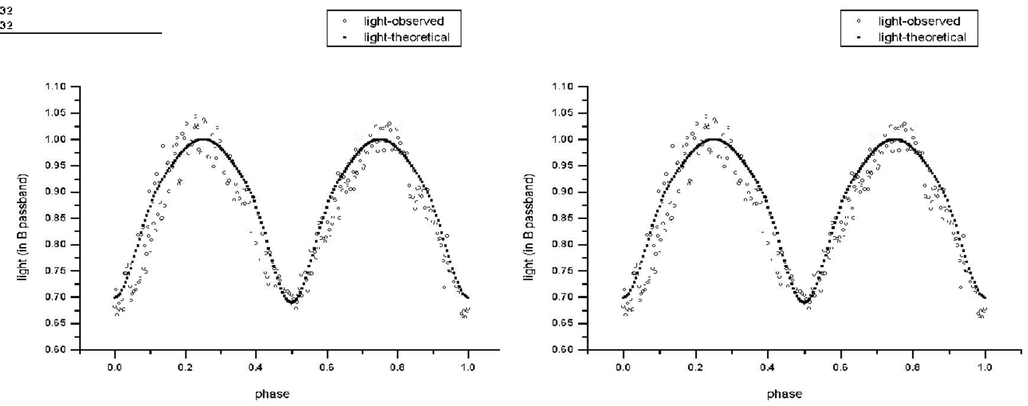


A plot of ∑(O-C)² versus mass ratio 'q' for values obtained using DC program for V data and B data

∑(O-C)² values for various 'q' values obtained from W-D solutions in both V and B passbands

S. No.	q	$\Sigma W(O-C)^2$ V data	$\Sigma W(O-C)^2$ B data
1	0.70	0.2182342	0.2881118
2	0.80	0.1954473	0.2621898
3	0.90	0.1794817	0.2458273
4	0.92	0.1783464	0.2452476
5	0.94	0.1786906	0.2458807
6	0.96	0.1791574	0.2469283
7	0.98	0.1828305	0.2498596
8	1.00	0.1903463	0.267826

Light curve in V and B passband. Solid squares represents theoretical values obtained from Wilson-Devinney solution and open circles represents observations done during 1981-92.



Discussions

The sinusoidal variations of the light curves with about equal amplitudes and the small period suggest that FZ Ori is a W UMa type binary and the large scatter in the light curves is usually due to mass transfer between the components or mass loss by the system, because of the common envelope or due to variations in the light of one of the components.

Unlike most of the W UMa type binaries, our light curves do not show any asymmetry which could be accounted for the system being in the quiescent phase during the period of our observations.

Assuming the components of FZ Ori to be main sequence stars, the following absolute parameters were deduced:

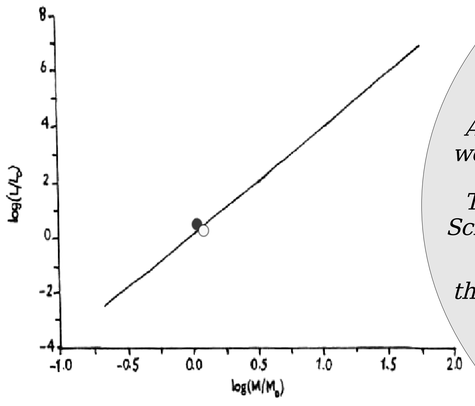
M_h=(1.26±0.03)M_{sun}, M_c=(1.12±0.03)M_{sun}; R_h=(1.22±0.03)R_{sun}, R_c=(1.14±0.03)R_{sun}; L_h=2.214L_{sun}, L_c=1.936L_{sun}

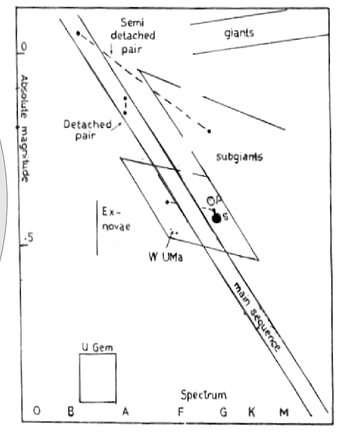
The distance of the binary was found to be 111.68pc. From the derived parameters and using the Schaller evolutionary model (Y=0.3, Z=0.02), the age of the binary was found to be around 1-5 Gyrs.

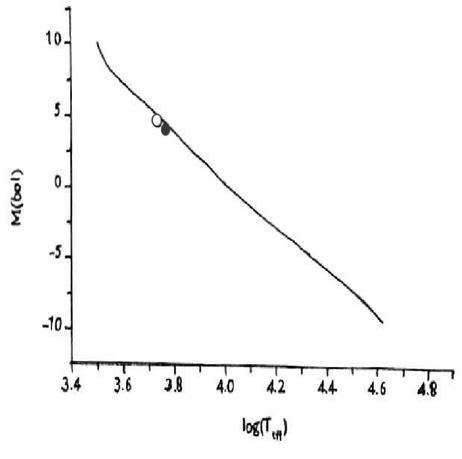
A plot of log T_{eff} versus M_{bol}, log(M/M_{sun}) versus log(L/L_{sun}) and log(M/M_{sun}) versus log(R/R_{sun}) show that both the components lie very near to the main sequence.

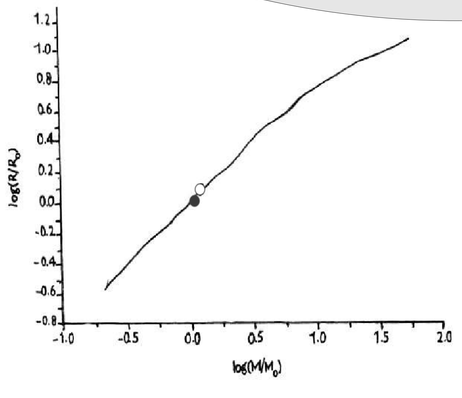
The positions of the components on the H-R diagram shows that they fall within the region for W UMa type binaries and the position plotted on the period versus spectral type diagram shows that it comes under contact category, lying very close to the zero-age critical contact curve.

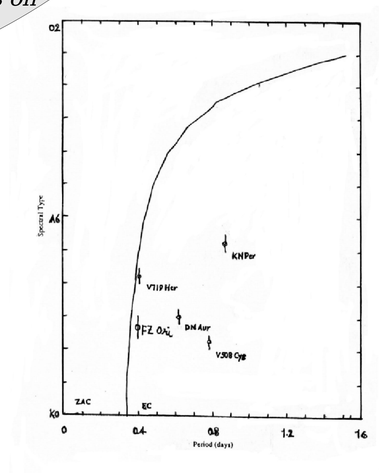
However, further photometric observations in various passbands and spectrographic observations are needed to check if the values of the spectral types obtained are consistent with those obtained photometrically and to look for any variations in the intensity of the spectral lines indicative of the surface activities on the stars.











The light curve analysis was done using the Wilson-Devinney program keeping the following parameters fixed: mean effective temperature of the primary $T_{e,h}$=6030°K corresponding to the spectral type G0; the gravity darkening coefficient G_h,G_c=0.32; bolometric albedoes A_h,A_c=0.5; eccentricity e=0 and F_1=F_2=1; and limb darkening coefficient X_h,X_c=0.6.

Computations were carried out for each of the V and B data using the DC program of the W-D method, for each of the selected 'q' values, by varying the parameters viz. i,L_h,T_c alternatively till the sum of the residuals, ∑(O-C)² showed a minimum at q=0.92 and the corrections to the parameters became smaller than their probable errors.

From the parameters obtained from the DC program, the LC program was run and the theoretical light curves were obtained. The quality of the fit was checked by performing Chi Square test on the ∑W(O-C)² values obtained and the confidence levels were found to be about 99% for the data in both the filters.

References:

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