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Light and period analyses of two ultrashort binaries KIC 8758716 and KIC 10855535

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Light and period analyses for two ultra-short binary systems, found by Kepler Space Telescope were carried out for the first time, using PHOEBE code. Analysis of period variations for KIC 8758716 system, shows mass and angular momentum loss with rates $\dot{m} = 1.087 \times 10^{-12}$, $\Delta J = -3.99 \times 10^{36}$kg.m yr^{-1}, respectively. However period analysis of the KIC 10855535 indicates a sinusoidal variation indicative of presence of a third body orbiting the system with period 412 d. In addition analysis of photometric light curves (LC) were performed in both detached and over contact modes. The results of analysis indicate that these systems are in detached configuration rather than contact, consistent with the Stepien's theory of angular momentum loss (AML).

I. INTRODUCTION

In recent years, the different projects e.g. COROT, MACHO, OGLE, Kepler, etc. Proposed to study and find exoplanet objects, provided vast amount of photometric data and as a side product data for large number of eclipsing binary and other type of variable stars. In this study of eclipsing binary we purpose to study and determine the orbital and physical elements of some ultrashort period or detach over contact binary stars. The over contact W UMa stars are class of binary stars, in which both of the components fills their roche lobes and form a common envelope, these kind of E.B usually have mass ratio between 0.2-0.5 however their periods between 0.1-1.5d and they have spectral type between F-K. As pointed of out above since these type of binaries form a common envelope, therefore the surface temperatures of the components in a system are close a each other. Binnendijk(1970) divided the contact systems in to, two categories based on LC morphology i.e. class A & W type binaries. The W subtype have deeper primary minimum in their LC produced through occultation of smaller component by bigger one. While in A-subtype the primary of the LC is a transit.

II. PERIOD VARIATIONS

A. variations in the period of KIC 8758716

To study the period changes of the system, we have collected the Eclipse Time Variations (ETV) values from Conroy et al. (2013). The ETV are plotted against the corresponding barycentric Julian Dates (BJD). All the collected data were converted to the a common Epoch using the following linear Ephemeris,

$$T_{minI} = BJD\ 2454953.673258 + 0.107205E \qquad (1)$$

then the ETV data were plotted against BJD, shown in Fig. 1, and is roughly fitted by a downward parabolic curve described by the Eq.

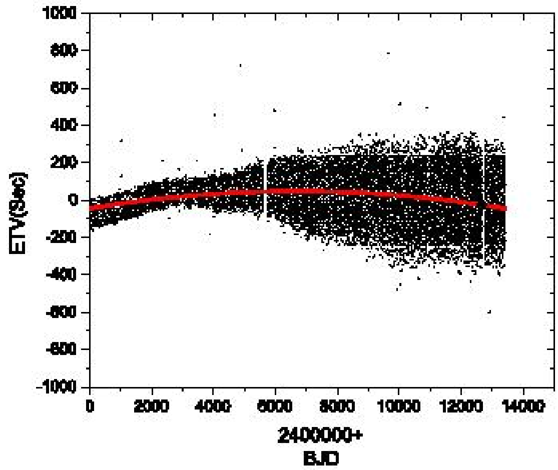

FIG. 1. Representation of the ETV residual values (Points) and its description by a downward curved parabola (continuous curve)for KIC 8758716.

$$a_1 x^2 + a_2 x + a_3 = 0 \qquad (2)$$

where,$a_1 = (-2.05491 \pm 0.04788) \times 10^{-6}$, $a_2 = (0.0275 \pm 6.612) \times 10^{-4}$, $a_3 = -44.188 \pm 1.914$. The residuals between the fitted parabola and $O - C$ normal points are displayed in Fig. 2, as obvious from Fig. 2. these residual indicate no significant variations (see the subsection V.B for interpretations and discussions)

B. Period Variations in KIC 10855535

ETVs for this system are plotted in FIG. 2, as evident from the Fig. these values indicate a sinusoidal behavior, which can be fitted by a sin curve with the following particulars:

$$Z = Z_0 + A\ sin(\omega t + \phi_0) \qquad (3)$$

Where $A = 138.54 \pm 0.22$ Sec, $\omega = 0.0024187 \pm 0.0001 d^{-1}$, $(\phi_0 = 0.969 \pm 0.002)$, $Z_0 = 54.71 \pm 0.16 sec$ And corre-

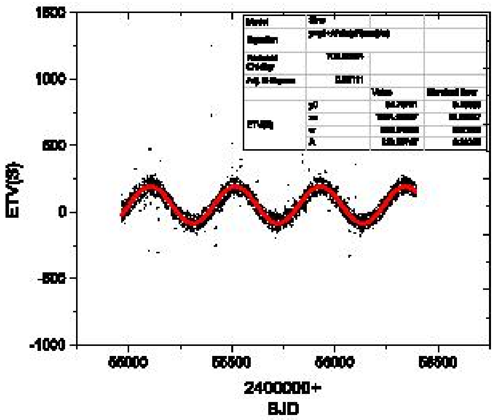

FIG. 2. Representation of ETV/BJD (points) and sin fit (continuous curve)for KIC 10855535.

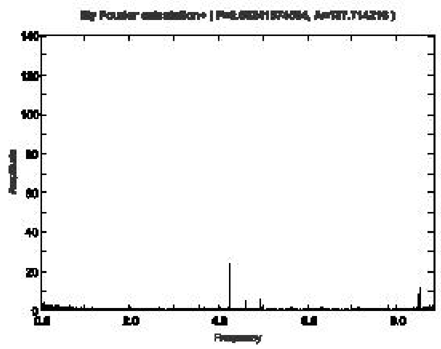

FIG. 3. Frequency spectrum of ETV for KIC 10855535.

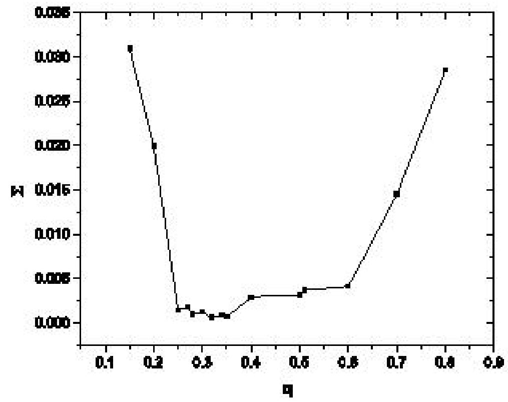

FIG. 4. The relation between qs and Σ s for KIC 8758716.

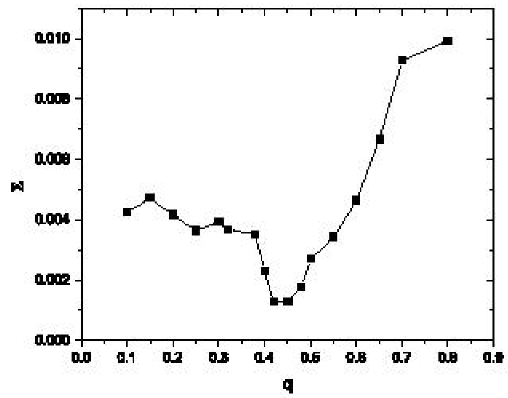

FIG. 5. The relation between qs and Σ s for KIC 10885535

sponding period $P_3 = 413 \pm 17d$. For more discussions and interpretation see section IV. the parabolic behavior of O-C curve described in section and indicated in Fig. 1, implies secular period decrease which can be attributed to the angular momentum loss (AML) from the system. Moreover the periodic changes of the residuals plotted in Fig

III. DATA REDUCTION

In this study of eclipsing binaries we have used photometric data from Kepler Space Telescope mission (2009), which were collected during years 2009-2012, morder to have accurate filtering a results have, selected only for few nights of observe these observation were obtained in wide range pass band 430-780 nm. We use PHOEBE code to obtain LCS solutions use of PHOEBE require suitable input parameters, for this purpose we have selected over contact W UMa mode of the program and accor-dance to this mode we set the reflection albedos A1=A2=0.5, and g1=g2=0.32, appropriate to convective envelope. The lambda darking coefficient, were read automatically from Van Hamm (1993) in accordance input temperatures for the components. Since there exist no spectroscopic observations of the system. Therefore we proceeded to find the photometric mass ratio (q) through a synthetic q-search method, by setting the value of q to set of values (0.1, 0.2, 0.3, etc.) and for each value of q, we adjusted the other main parameters (i.e. T1, T2, Ω1, i, L1, the luminosity) of the binary system so that to make the χ^2 function Minimum Σ errors to be less, then these values of the ?s one plotted against the respected q-value, in Figs and the value for the q & selected this value of q as a variable and then we have adjusted the other parameters i.e. T1, T2, Ω1. so that to minimum the χ^2 function value, and also find best fitting and super position of observed and the synthetic LCS with each other by eye inspection. The obtained parameter value one tabulated is table 1, and LCS are plotted in Figs 2. During the fitting process, in same ease to best fit the observed and synthetic, it was necessary to assume dark spots the primary and or secondary components these spots are arranged in table 2.

However, It was observed, during the process of fitting

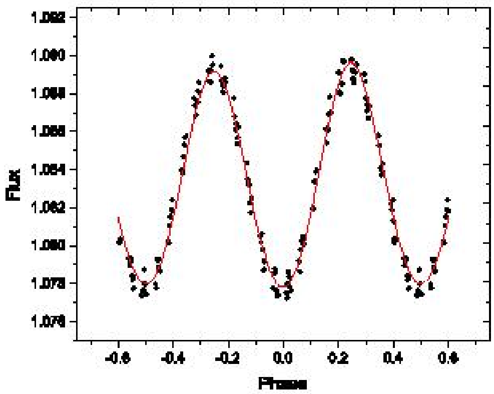

FIG. 6. Synthetic LC (continuous curves), obtained using contact W UMa mode of the PHOEBE program observed LC (filled circles), for KIC 8758716.

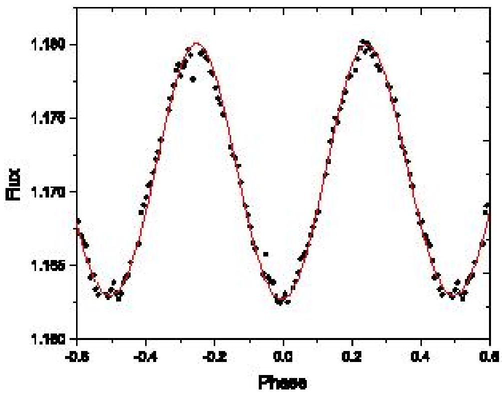

FIG. 7. Synthetic LC (continuous curves), obtained using contact detach mode of the PHOEBE program observed LC (filled circles), for KIC 10855535.

to get the best LCs solutions the assumption of a dark spot with particulars given Tabel 1 below was necessary. The mode was switched to the detached mode, however by keeping the parameters at the same values the errors of the parameters particularly the $\Delta\Omega$ in this mode were reduced to considerably lower values.

these residual indicate a sinusoidal behavior, which can be fitted by sin curve with the following particulars:

IV. RESULTS AND DISCUSSIONS

A. Period variations

Visual inspections of the Fig. 1 i.e. ETV for KIC 8758716 system indicates, a general trend of ETV points indicates a downward curved parabolic variations with particulars, described in section 2, which indicates a secular decrease in the orbital period with a rate of dp/dt=-0.002 sec/yr. This decrease in orbital period may be attributed to mass and angular momentum loss from the system with a rate of $\dot{m} = 1.10 \times 10^{-12} M_{\odot} yr^{-1}$. Referring to the table 1, the temperatures of the components stars are relatively low, close to F-G spectral type and capable of mass and angular momentum loss(AML) from the system through magnetic braking, therefore the decrease in period. The rate of angular momentum loss from the system calculated by using the period decrease is $\Delta J = 3.99 \times 10^{36}$ kg.m/yr which is at least 3-4 orders of magnitude lower than the regular mass losing systems. This is consistent with the Stepein (2006, 2011), theory of the mass and angular momentum loss and evolution of short period low mass close binaries, according to which theory, they had no enough time within the age of the Universe, for the components evolve and fill their Roche lobes and to form a contact system.

Apart from the above statements regarding the AML theory, to get an accurate LC solution, we started with over contact W-UMa mode of the PHOEBE program, but, despite relativity good fit of the LC and reasonably low errors of the adjusted parameters, the configuration of the system obtained using the obtained parameters indicated a detached one. Moreover the solution of the LC obtained in detached mode gave relatively more ac-

TABLE I. The results obtained through LCs analysis using PHOEBE program

Param	*Valuesfor* − *KIC*8758716	Values for KIC 10855535
e	0.001±0.003	0.001±0.002
i(Deg)	67.300±0.069	62.820±0.680
$T_1(K)$	6550±5	6850±4
$T_2(K)$	6550 ± 5	6500 ± 4
Ω_1	4.088±0.009	3.984±0.008
Ω_2	3.986±0.009	3.922±0.007
q	0.325±0.0013	0.455±0.001
L_1	11.370±0.014	10.564±0.013
$el3$	-	0.070±0.001

TABLE II. Absolute physical and orbital parameters, of the XZ And system obtained through LC analysis

Param	*ValuesforKIC*8758716	Values for KIC 10855535
Period(d)	0.107205(adopted)	0.112782(adopted)
$A(R_{\odot})$	0.4983	0.502
$M_1/M_{\odot}$	0.109	0.092
$M_2/M_{\odot}$	0.035	0.042
$R_1/R_{\odot}$	0.134	0.144
$R_2/R_{\odot}$	0.0613	0.087
$L_1/L_{\odot}$	11.370 ± 0.014	10.564 ± 0.013
$L_2/L_{\odot}$	−	−
$M_{1,bol}$	10.303	9.584
$M_{2,bol}$	8.613	8.256

curate parameters with lower errors of estimations (see table 1). Fig 2, i.e. the ETVs for KIC 10855535 system, indicate a very regular sine curve, this was attributed to the presence of a third body orbiting with a period of 413d around the barycenter of the system. The mass and orbital radius of which and estimated below.

B. Cause of quasi periodic variation

The cyclic variation in the orbital period may be caused by one of the followings,
a) Apsidal motion,
b) Magnetic cycle effect,
c) Light Travel. Time effect (LTTE).
Requirements for apsidal motion, are that variations modulating the orbital period should be strictly periodic and also eccentric orbit is a must, however these are not supported by the finding of this paper, see Fig 1, the other requirement is that the O-C residual points for primary and secondary eclipses should be in complete opposite phase which are again not supported by the results of present paper, as they are in phase agreement (see the Fig.1). On the other hand extrem regularity of ETVs curve and the period 412 d found for cyclic variation, do not favor magnetic cycle effects, as for instance these magnetic cycle duration for Sun is 11 yr, for U Sge, 9 yr, for UW Boo 22 yr. Therefore this period 412 d, may be attributed to the presence of an additional third body in orbit around the barycenter of the system the particulars of which may be estimated as below:

Assuming a third body with circular orbit and coplanar with the system, then we may estimate the the radius of the orbit and a lower limit to the mass of the possible third body using the equation 5 below, by putting the orbital inclination of the presumed third body $i_3 = 90°$ and using the amplitude (A), from the Eq. 3, we get (see Mayer 1990),
$a_{12} sin i_3 = A \times c$

$$F(m_3) = \frac{(a_{12} sin\ i_3)^3}{P_3^2} = \frac{(m_3 sin\ i_3)^3}{(m_1+m_2+m_3)^2} = \frac{1}{P_3^2}[\frac{173.15A}{\sqrt{1-e^2 cos^2\omega}}] \quad (4)$$

where the quantities,
ω = longitude of periastron,
$a_{12} = 0.227AU$, orbital radius of the eclipsing pair relative to common center of mass,
$m_1 = 0.092M_\odot$, mass of the hotter component (primary),
$m_2 = 0.042M_\odot$, mass of the cooler component (secondary)
$e = 0$, orbital eccentricity of the third body orbit
$P_3 \simeq 412 \pm 17$ d, orbital period of the third body
and $A = (1.5 \pm 0.002) \times 10^{-3}$ d, the semiamplitude of the LTTE

based on these values the estimated mass of the possible third body $m_3 \simeq 0.096 \pm 0.006\ M_\odot$ and its orbital radius $a_3 \simeq 0.387 \pm 0.065 AU$.
The mass and period of the presumed third body found are are comparaable to the primary mass, however its orbit is relatively low this might be a reason for regular sinosidal period change..

V. CONCLUSION

The main conclusions, drawn from the results are: system KIC 8758716 is losing mass and AM with rates and $\dot{m} = 1.087 \times 10^{-12}$ $\Delta J = -3.99 \times 10^{36}$kg.m yr^{-1} respectively. The system KIC 10855535 is a Tertiary system. The results in this paper confirms the Stepein theory of AML regarding low mass short period close binaries.

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