Study of Eclipsing Binaries: Light Curves & O-C Diagrams Interpretation

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Abstract: The continuous improvement in observational methods of eclipsing binaries, EBs, yield more accurate data, while the development of their light curves, that is magnitude versus time, analysis yield more precise results. Even so, and in spite the large number of EBs and the huge amount of observational data obtained mainly by space missions, the ways of getting the appropriate information for their physical parameters etc. is either from their light curves and/or from their period variations via the study of their (O-C) diagrams. The latter express the differences between the observed, O, and the calculated, C, times of minimum light. Thus, old and new light curves analysis methods of EBs to obtain their principal parameters will be considered, with examples mainly from our own observational material, and their subsequent light curves analysis using either old or new methods. Similarly, the orbital period changes of EBs via their (O-C) diagrams are referred to with emphasis on the use of continuous methods for their treatment in absence of sudden or abrupt events. Finally, a general discussion is given concerning these two topics as well as to a few related subjects.

Keywords: eclipsing binaries; light curves analysis/synthesis; minima times and (O-C) diagrams

1. Introduction

A lot of time has passed since the primitive observations of EBs made with naked eye till today's space surveys. In the meantime, small or large telescopes equipped, or not, with photometers or CCD cameras were used. Later, due to the great technological progress, earth-based observations were carried out with robotic or automatic photometric telescopes, while today, observations on EBs are received from the various space missions. The later provided us with a huge amount of data and together with those from earth yield to the conclusion that EBs are not rare. See, for example, some photometric survey results of OGLE, MACHO, EROS-2, etc., not to mention the number of eclipsing binaries from Kepler.

To be more specific: A catalogue of 1575 contact EBs fainter than I = 18 mag are identified in the OGLE-I database in the selected directions toward the Galactic bulge and the Galactic bar [1]. Meanwhile, 11,589 EBs have been identified in the Galactic disk fields from OGLE-III survey [2], while over of 450,000 EBs and ellipsoidal binary systems have been detected towards the galactic bulge from the OGLE project [3].

Moreover, a search for EBs in the central regions of SMC and LMC collected from OGLE-II showed 1500 and 3000 eclipsing stars in these two galaxies, respectively [4]. The foregoing mentioned numbers became 8401 and 40,204 from the OGLE-IV survey [5], while 493 were new discoveries from a catalogue of 1768 EBs detected in the outer region of LMC by EROS-2 [6]. Similarly, the CoRoT space mission equipped with four CCDs, collected 177,454 light curves, from which 2269 EBs were detected [7].

The benefits from EBs study were well known long ago, and this is the reason of their continuous observations. Much information for stellar structure and evolution can come out of them; special important is their role in providing fundamental data for stars as are masses, radii, etc. The latter is

achieved via the study of their light curves, while the first through the study of their orbital period variations. Furthermore, EBs were used to trace anomalies or differences in the brightness over a stellar surface, while it is possible to determine empirical limb-darkening coefficients or gravity darkening exponents. Finally, as an eclipsing pair may consist of similar or absolutely different stars, it is a challenge for the stars' evolution.

To the foregoing mentioned benefits, two more and very important were added: (a) EBs can be used as distance indicators if they are found in clusters or other galaxies except our own. Thus, the distances of SMC [8,9] and LMC [10] have been measured, as well as this of the Andromeda galaxy [11,12] and that of the Triangulum galaxy, M33 [13,14]; (b) EBs can provide useful information for other planetary systems, since the recent results from the Kepler mission yield the discovery of planetary companions, transiting exoplanets [15,16], which can provide useful information for other planetary systems.

On the other hand, in spite the large number of eclipsing binaries and the huge observational data obtained mainly by space missions, the ways of getting the appropriate information for their main physical parameters etc. is either from their light curves and/or from their period variations via the study of their (O-C) diagrams. For this reason, the main scope of the present is to pass briefly through what has been done up to now concerning the light curves treatment of EBs, while the ways of facing their orbital period changes is examined, too.

2. Treatment of the Light Curves of Ebs

2.1. Light Curves of Various Ebs and Models for Their Analysis

Different models have been proposed so far to explain the variations observed in light curves of Ebs, which consist of a gravitationally connected pair of stars, and in which the inclination of their orbital plane to the line of sight is such that permits mutual eclipses to be detected. Classical Ebs are usually divided into three main categories based on the Roche model, which is used in all codes or programs used today: detached, D, semi-detached, S-D, and contact systems, C. Moreover, a historical division, which is also very often used, is that of: Algols for D type, β Lyrae for S-D type and W UMa for contacts, from the prototype of each category observed.

Moreover, contact binaries were divided to two sub-groups, A-type and W-type, according to which star is eclipsed during the primary minimum. Moreover, other systems are characterized as near contact, marginally contact, and over-contact ones.

To the foregoing basic division, some other classes and/or sub-classes have been reported during the last 15 years, based either on earth data as are the oEA systems, i.e., EBs of Algol-type where one of the components is an oscillating star, (e.g., as referred to in [17–22]), or on data from space missions, as is for example the totally eclipsing Algol-type system whose primary component shows over 50 pulsation frequencies [23]. To them, EBs with very low mass ratios [24] could be added, as well as hot Algols in our Galaxy and in SMC and LMC.

As concerns the light curves analysis of EBs to get the fundamental elements of the two component stars, various programs have been proposed so far. Starting from the simplest spherical model, where the two members of a binary were considered spheres being well inside their corresponding Roche lobes, soon the two stars' shape changed to ellipsoid, which is more realistic since the two components should be considered deformed because of their axial rotation, their mutual tides etc.

Thus, various programmes have been developed for getting the two stars' fundamental parameters. Since is not possible to mention all of them, we restricted to the mostly known and widely used, which are the Russell–Merill model [25], WINK [26], and the frequency domain method, FDT. The latter was described in a series of papers and then in a book [27], and these three methods can be characterised as the old ones.

From the old methods, FDT is the mostly used, since in the last decades of 20th century it was new, quite easy to be used yielding to the computation of the most significant elements of the EBs.

Besides, it could be applied to any kind of system, (D, S-D, or C), as well as to any kind of eclipse, (total or partial). The simplest to be analysed were detached systems, but S-D and contact were also analysed after taking into account the photometric perturbations, as given in [28,29], and tidal and rotational distortion inside and outside eclipses for any kind of them, as described in [30,31]. A large number of classical EBs of every type were analysed with this method, a sample of which can be found in the works [32–38].

At the same time, the development and new capabilities of computers permitted many researches to write their own programs or codes, like LIGHT [39], LIGHT2 [40], the BINARY MAKER [41], and many others such as EBOP [42], and this presented in [43]. Even so, the most known and used of such codes is the W-D code [44], which is still in use after passing through some modifications and improvements [45], while the latest and much more powerful program is PHOEBE [46], which is continuously improved, too.

The foregoing mentioned codes are characterised as new methods of light curves treatment of EBs. From them, W-D code and PHOEBE are mostly used due to their continuous improvement. Besides, is mentioned that sometimes other programs are firstly used to get a set of preliminary elements for a particular eclipsing binary before applying W-D code or PHOBE. For example, the BINARY MAKER is very often used, e.g., in cases of AK Her [47] and II UMa [48]. Similarly, a simple spherical model & EBOP code were used for WR 20a [49]. Further, the W-D code was used to get solutions for some of the new discovered EBs outside our own Galaxy from the various space missions.

The big difference between the old and the new methods is that in the old ones the various used programs were really analysed an observed light-curve to get the two stars' basic elements, while what characterized the new methods is synthesis described in detail by many authors in [50,51].

Furthermore, for eclipsing binaries in cataclysmic variables, CV's, in low mass x-ray binaries, LMXBs or high mass X-ray binaries, HMXBs, in Wolf–Rayet stars, WR stars, in symbiotic systems etc. similar programs and codes have been developed, too. The difference from those already mentioned is that they have been constructed in such a way to be suitable to face the peculiarities of these kinds of close binaries, as are for example atmospheric eclipses for WR-O stars, or an accretion disc around the gainer component. Thus, these codes were prepared to be in agreement with the proposed theoretical models, as are for example those described in [52,53], suitable for spots and for CVs, respectively.

2.1.1. Aldedo, Limb and Gravity Darkening

It is worthwhile to mention that in all of the forgoing mentioned programs and codes, a number of separate functions, or routines and sub-routines are used to compute various needed quantities, while standard values are given to some elements. Besides, as regards the model atmospheres used, except the classical black body model others are also used as the Kurucz, or the BaSel ones, while albedo, limb-darkening coefficients, and gravity-darkening exponents are kept constant giving them their theoretically values.

So, albedo is taken equal either to 1.0 for hot or 0.5 for cool stars, respectively. As concerns limb-darkening coefficients, various tables exist in the literature [54–57].

Regarding the gravity-darkening exponent, β, its standard values are: $\beta = 0.25$ for purely radiative transfer and $\beta = 0.08$ for stars with convective envelopes. Moreover, the phenomenon of gravity darkening attracted the interest of many investigators like [58,59] etc., while it was examined for some specific stars like Algol [60]. In real stars, a smooth transition is achieved between the two energy transport mechanisms and, thus, β can take all intermediate values, as referred in [61]. The latter was confirmed from the analysis of the observational data of a number of EBs of S-D type, as shown in [62,63].

In the meantime, and since, of all classical EBs, those of the most interest are contact systems, because of the mutual interaction between the two components, many different models have been proposed especially for them, among which the following are mentioned: the contact discontinuity model, DSC, the thermal relaxation oscillation model, TRO, and the angular momentum loss model, AM.

2.1.2. Dark Spots and Corresponding Dark-Spots Models

On the other hand, some anomalies yielding to asymmetric light curves were faced as due to spots, dark spots, i.e., cooler than the surrounding photosphere. The first complete description of the effects of circular or elliptical spots at any longitude and latitude from rotating spherical stars was given by [64], followed by the development of many codes especially for EBs of RS CVns-type. From the big number of such programs developed and used by individuals or groups of researchers we are limited to [65,66] only, since in the meantime all of the so-called new analysis methods were taken into account circular dark spots, to be used for stars with convective envelopes, i.e., capable to develop magnetic activity like our Sun.

The today used spotted models usually considered one or two circular spots, while the computed parameters of the spots are their radius, location, (longitude & latitude on the star's surface), and temperature difference from the surrounded area [67]. A lot of such studies exist concerning the light curves analysis of many individual stars, while general information for spots on the surfaces of single and binary stars can be found, too, as in [68].

Even so, there were many problems using these so-called spotted models with the biggest being that of the uniqueness of solution, for which much discussion has been had, because of the pretty good light curves fitting received from various spot(s) sizes and/or spot(s) positions.

On the other hand, and with the aid of spectroscopy it was possible to follow the line profiles due to spot(s) activity over the course of the stars period of axial rotation. Thus, it was found that, in classical EBs, dark spots were detected on the surfaces of the late type component of Algols, and on one or both members of W UMa-type stars. Similarly, they were detected on CVs, or on one or both members of RS CVns-type binaries. However, not all of this class of variables belong to EBs.

The existence of dark spots on the surface of the foregoing mentioned type of binaries was confirmed from simple and/or continuous photometric observations, as well as with high-resolution spectroscopic data. So, many stars were monitored, and their data were subsequently analyzed with simple spotted models. Great has been the aid of APT or RT towards this direction, as various groups of scientists all over the world made continuous photometric observations to specific group of stars and especially to magnetic active ones.

Spots are usually connected to flare activity that has been detected in many single or binary variables and many reports there exist for individual stars, while a homogeneous sample of all flares occurred in active stars from the EUVE data has been presented, too. Similarly, flares have been detected in some EBs either from ground-based observations, or from space. Regarding the first, from the big number of individual EBs referred, here, only the four [64–72] are mentioned. They concern the stars X Tri, GSC 2314-0530, GJ 3236 from a campaign between 2014 and 2016, and BX Tri from a campaign between 2014 and 2017, respectively. As regards space observations, only two are mentioned concerning close binaries observed by Kepler [73,74].

3. Treatment of the (O-C) Diagrams of EBs

3.1. Period Variations

Our knowledge of period changes in close binaries is mainly and almost exclusively based on EBs and especially on the analysis of their (O-C) diagrams, which carry much and valuable information. Thus, it is very important to distinguish the apparent from the real orbital period variations [75], while it is also very important the way with which such a diagram is constructed and analysed.

Observations have shown that in general there are small but definite orbital period variations in a close binary due to various reasons. Strictly periodic and of alternating sign period changes for example can be caused by apsidal motion or by the presence of a third body in a close pair, (apparent changes). They are easily recognizable one from the other, since the primary and secondary minima behave differently in each one of these two cases.

Both apsidal motion and light time effect have been investigated for many years and remain of interest among various researchers generally and from the theoretical point of view, as in [76,77].

As regards the apsidal motion hypothesis in an (O-C) diagram, it could provide remarkable results, as in the case of DI Her [78]. For this star various hypotheses were made to explain the disagreement between theory and its very slow rate of apsidal motion, which had been interpreted even as a possible failure of the theory of general relativity, GR. In Ref. [78], the problem was solved via a more detailed technique with the final result to be in good agreement with GR theory.

Concerning the light-time effect, it is produced by the presence of a third companion in the eclipsing pair. From the big number of studies on individual EBs there is evidence that many close binaries have distant tertiary companions [79–82]. Current observational estimates suggest that about more than 30% of all binary stars are in triple systems, while according to [83], the abundance of a third body in W UMa-type was found to be much greater than the estimated values concluding that most contact binaries exist in multiple star systems. General information for triple and multiple systems can be found in the updated Multiple Star Catalogue, MSC [84].

Moreover, investigators who combined old and new earth based results with the latest micro-lensing data were able to study these two phenomena in some particular EBs in both Magellanic clouds, e.g., the apsidal motion of three eccentric EBs in the LMC [85], the apsidal motion for 13 eccentric EBs in the LMC [86], and the light-time effect in some bright and some massive EBs in the SMC [87,88].

On the other hand, it is noteworthy to mention the perturbing effects of a third companion forming a hierarchical triple system with a close eclipsing binary discussed in [89,90]. In these cases, it seems very possible that the dynamical interaction of the third body could cause real and not apparent orbital period variations, as a simple light-time effect.

Moreover, from the continuous and long-term observation of various types of binary systems it was found that a large amount of EBs exhibits real orbital period variations, which in some cases are of quasi-periodic nature [91]. This latter kind of orbital period behaviour has been detected in Algols and W UMas from the classical EBs, as well as in eclipsing RS CVns and CVs.

Various theories have been proposed to explain the origin of the real orbital period variations with first the mass and angular momentum transfer and/or loss, e.g., [92,93] etc. This can be achieved through stellar wind, via the second Lagrangian point L2, or through a process in which when one of the two components fills its Roche lobe matter is transferred through the inner Lagrangian point L1 to its mate, (Roche lobe over flow, RLOF), if restricted to usual cases and not to sudden catastrophic events like novae or supernovae. These mechanisms act on different time scales produce short or long-term orbital period changes related to their evolution. So, theoretic al estimates of AML based on different assumptions for magnetic braking law for binaries in general and with solar-type components have been carried out [94–98]. Similarly, average mass transfer rates have been derived for Algols [99,100], for CVs, and other binaries [101,102], while a method to control the existing numerical instabilities during mass loss overflow in contact binaries has been proposed [103].

To the foregoing mentioned mechanisms to explain the real orbital period changes of EBs, and of close binaries in general, the development of magnetic activity cycles was added [104,105]. Because a theory to explain period changes as a consequence of magnetic cycles that may be periodic or quasi-periodic had been suggested [106]. Great has been the aid of APT or RT towards this direction, as scientists all over the world were able to observe continuously specific group of stars and especially the magnetic active ones. Thus, clear evidence of long-term activity circles was detected, as well as evidence of spot migrations. From the big number of such studies only two are referred [107,108].

3.2. The Construction of an (O-C) Diagram

The basic problems in the construction of an (O-C) diagram are the quality of the observational material and the time interval they cover. A general discussion is given in [109], while many studies

concerning the (O-C) diagrams of various stars can be found in [110]. Moreover, the efficiency of (O-C) diagrams as diagnostic tools for long-period variations have been examined [111,112], too.

Moreover, it is clear that long time intervals together with very small orbital periods mainly for contact binaries might yield to wrong results and conclusions, as for instance in the case of AK Her, whose light curves analysis and period study are described in [47].

Moreover, since the values of the C's are calculated according to an ephemeris formula, the shape of an (O-C) diagram is strongly depended on it, as is clearly demonstrated in the (O-C) diagram of AB And [113]. For this reason, some investigators use different ephemeris formulae to detect the existence of a possible hidden periodic term.

Furthermore, two distinct small problems have to be also considered: (a) to test the significance level of possible orbital period changes and (b) to extract the precise form of them, since the presence of small random variations might be intrinsic to the star. This must be considered very seriously especially after the realization that some primary components of Algol type EBs are pulsating variables, i.e., they belong to the oEA sub class of Algols as already referred [17–22].

3.3. Ways of an (O-C) Diagram Analysis

As regard the (O-C) diagrams analysis, the well-known linear and piecewise approximation, or step variation, as well as the quadratic one, i.e., the parabola fitting, were the first used to analyse the (O-C) diagrams of EBs. They might be good enough for some EBs, but not for all. So, later in contrast to these old methods, some new, continuous methods, have been proposed, e.g., [114–116]. It is mentioned in [114] that spline interpolation is used to join the various sub regions of the (O-C) diagram, while [116] is the last from a series of papers, and thus the former can be easily found.

As regards the work of the first investigators, a first application was made to AB And [113], while many others followed by various researches among whom some are mentioned [117–125]. In the application to AB And [113], it is clearly shown that from two different (O-C) diagrams -constructed using two different ephemeris formulae- the same results come out for the orbital period changes of this system analysed with the continuous method proposed in [114].

On the other hand, assuming that the orbital period variations are due to magnetic activity only, there is possibility to find the variation of the magnetic field of the active component through a new method, namely variable sine algorithmic analysis (VSAA) [126]. It analyses the orbital period in the joined time-frequency domain, and thus provides an accurate description of the time variation. This makes the method suitable for tracing variable periodicities and applicable not only to EBs, but to other stars and phenomena like the Blazhko effect, the solar spot cycles etc. as is demonstrated in [127,128], while similar properties are referred to have the method described in [129].

4. Discussion

After John's Goodricke idea in 1783 that eclipses can be a possible explanation for β Persei light variations, which was later spectroscopically confirmed, it was realized the importance of EBs. This early recognition of EBs significance yield to their continuous observations, since the studies of EBs is made either through their light curves or via the times of their minimum light.

Binary stars and especially EBs have offered a lot in our understanding the structure and evolution of stars in general. They have, thus, been the subject of many theoretical as well as observational studies. Besides, many Books have been written about from which the following for binary systems in general are mentioned [130–132]. Similarly, EBs were the main subject of many conferences, at some of which the developed programs for their light curves analysis were firstly presented, as is the LIGHT-2 and the BINARY MAKER in [40] and [41], respectively.

On the other hand, both earth based observations and space missions, with various subjects as main goals, provided us with a huge amount of data, and methods had to be developed to identify EBs out of them, as proposed in [133]. As a result, hundreds of new light curves of EBs not only in our

own galaxy, but in the Magellanic clouds as well as in the Andromeda galaxy have been discovered. Similarly, a huge amount of minima times was provided by the last years' space surveys.

In spite of the huge amount of data, both the light curves and the (O-C) diagrams of EBs are treated using old well-known methods, which although improved or modified have the same basis. This was the main reason for which these methods were briefly discussed here as an honour to the pioneers of this subject and as recognition of their contribution.

It is amazing to compare the past with the present in photometry of EBs. In the past early observers, using their simple photometers, could observe only one eclipsing binary each time, while today thousands of photometric data and light curves of EBs are available in various databases. Some of these data have been already analysed, yielding to some interesting results, as is the observed Doppler boosting in some Kepler light curves [134].

Similarly, it is astonishing to think of the near future when huge amounts of data of the order of terabytes, or more, will need to be analysed, even if the first clearing will be made automatically, as proposed [135]. However, their storage, security, and cost have to be very seriously considered. Moreover, our main concern has to be what new information will be added to our knowledge of EBs from the analysis of such huge amounts of data except statistics.

Regarding the methods used to get the principal parameters of the two components of an EB via their light curves, we characterized them as old and new ones. The big difference between the old and the new methods is that in the old ones the various used programs were really analysed an observed light curve to get the two stars' basic elements, while the basic characteristic of the new methods is synthesis, as already referred. The word synthesis used in this case is rather a good choice. It comes from the Greek word σύνθεσις, originating from the verb συνθέτω = συν-θέτω, meaning to put things together. Indeed, in this approach, the investigator choosing the values of some particular parameters and leaving the rest free, tries via the code to get the best fitting for the light curves of a particular EB, achieved when all elements are put together. It is similar to the work of a music composer—συνθέτης in Greek, i.e., a word of the same origin—who tries to achieve a nice music result by putting many different organs to play together.

Moreover, and although the FDT method was the most used from the old ones, all others were also used. For example, the WINK was used for the light curve analysis of GO Cyg [136] and WZ Cyg [137], while the light curves of WZ Cyg were also analysed with W-D code. Similarly, the light curves analysis of AG Per referred in [33] was carried out with three different of the characterized as old methods.

On the other hand, some irregularities like the O'Connell effect detected in the light curves of EBs were confronted using various dark spots models, as for instance these presented and described in [66,67]. Similar phenomena, i.e., dark spots, were detected in EBs from the various space missions, as these are referred to in [138,139]. Moreover, and for the completeness of our task, is mentioned that except dark spots, bright and/or hot spots are also used to explain some of the observed light curves anomalies, in agreement with the theoretical models, since the physics of the two kind of spots (dark or hot) is absolutely different.

Moreover, other irregularities are faced using a disc model. Among the many existing examples, two are mentioned here, namely the case of DL Cygni [140], and that of the eclipsing symbiotic AR Pavonis [141].

Today, both the characterised as new codes, that is, W-D and PHOBE are widely spread and almost exclusively used. For example, PHOBE was used for the light curves analysis of HIP 12039 [142]. Further, it is worthwhile to mention that the special code of PHOBE prepared for the determination of the principal parameters of detached EBs from OGLE project [143], had to be modified to be used for EBs from Kepler mission [144], because of the superb quality of the observational material of the latter. Concerning the W-D code, it was used to get solutions for some of the new discovered EBs in LMC and SMC as well as for the light curves analysis of some EBs from OGLE. Thus, although the light curves of the new discovered EBs from the various space missions are analysed using mainly W-D code or

PHOEBE, the use of other known programs and codes to which we referred here cannot be excluded, as the case of the eclipsing binary WRa, already mentioned [49].

On the other hand, the treatment of (O-C) curves of EBs was discussed, since it is connected with orbital period changes and though it with their evolution. For this reason, some theoretical works connected with the evolution of various kinds of EBs, or for close binaries in general, were mentioned, too because systematic mass loss, mass exchange, possible existence of magnetic cycles etc. are associated to the long-term secular period variations. Moreover, relations connecting the rate of orbital period variation with the significant parameters of their evolution have been developed under non conservative conditions in a fundamental level of description [145].

Moreover, the scenario according to which contact EBs will merge in one single star was confirmed from direct observations [146], while the very low mass ratios of some of these systems had made investigators to suppose and expect such a result long ago.

Concerning the influence of possible existed spots on the surface one of the components in the (O-C) diagrams of close binaries it has been examined some years ago [147], while recently this subject was also discussed together with the possible existence of third components in 41 EBs from Kepler survey [148]. Moreover, according to [149] these first findings of Kepler mission support the idea that the formation of close binaries involves the deposition of angular momentum into the orbital motion of a third component.

As regards the detection of a third companion in an EB from its (O-C) diagram, it is made through the light time effect, as referred, and the findings has shown that tertiary is a quite common phenomenon. From the many such studies, the spectroscopic search for faint tertiaries in contact EBs is mentioned [148], as well as the novel proposed method to determine compact triples [150].

On the other hand, it is interesting to find the kind of the third body. In most cases, it was found to be a star, but there are cases where the third body has sub-stellar mass as reported in [151,152]. This is in agreement with the early results from Kepler mission yielding to the discovery of stellar and planetary companions in binaries, as already referred in [15,16].

Moreover, the case in which one of the two components of an EB is a pulsating star was also mentioned, since this phenomenon was detected in some Algol type systems: the oEA class, based on earth observations as already referred to in [17–22] and in [153]. Similarly, EBs with pulsating components have been reported from space missions results, e.g., with a δ Scuti type, or a hybrid δ Scuti [154], and that mentioned in [23], or a Cepheid, (the eclipsing Cepheid OGLE-LMC-CEP-0227 in the LMC) from micro-lensing survey, [155], while other cases have been also referred [156].

Furthermore, some irregularities detected on the light curves of some EBs were treated supposing the existence of an accretion disc around the gainer component. A search for eclipsing binaries that host discs has been made [157], and only one of the many existing examples is given here [158], and it is related to the new class of DPVs. This new category of EBs is nothing else but hot Algols. From this, as well as from the new class of nascent EBs with extreme mass ratios [24], we expect to learn much for their construction and evolution.

As a conclusion, it can be said that the existent codes for the light curves analysis/synthesis are good enough for getting at least a first set of the fundamental parameters of EBs, while some modifications may be necessary. Such modifications will help to confront not only some observational irregularities or anomalies, but also face other problems, e.g., the superb quality of the light curves from Kepler mission.

As concerns the (O-C) diagrams, although sudden or abrupt changes cannot be excluded, they are worth treating with great care, especially when one of the components is a pulsating star. Moreover, remember that as much more time interval space is covered, more reliable results will be obtained.

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