Report on Mr. **Miloslav Zejda** Ph.D. Thesis **"Analyza svetelnych kr'ivek* zakrytovych dvojhvezd"**

The thesis consists of 2 parts containing 8 chapters and an appendix with tables. It is accompanied with bi-lingual abstract and signed author's statement. Its subject corresponds to 'Analysis of light curves of eclipsing binaries'. The thesis is written in Czech. Though I have no formal education in Czech, yet by scanning phrases several times I was able to figure minute technical details in the text. Actually the reading process was not tiresome and gave me some satisfaction. Thus hereby I declare that I am **competent** to comment on the subject and content of Mr. Zejda thesis. Obviously I shall not comment on the language, except by mentioning that the explanation appeared smooth and logical and thus facilitated my reading/understanding of the content. Also, I have no comment on practical applications of this work except stating that while achivements in pure science have no direct practical use, yet by raising general level of our understanding of nature facillitate both social and economical development.

Eclipsing binaries belong to the oldest subjects of astrophysics, yet recived renewed interest in recent days as precision standard candles and accurate stellar evolution diagnostic tools. In part I the author reviews virtually all methods ever employed for analysis of stellar light curves. Part II reports an impressive amount of Mr. Zejda own study of TW Dra. In this respect the thesis title should not use plural form. Next, I am used to all textbook/method description beeing covered in part I and part II containing only new results. Mr. Zejda choose in Part II to interlace discussion of his new results with description of standard procedures, e.g. CCD reductions, CCF application etc. My remarks above concern no science but purely **editorial** issues, and may stem from different local tradition.

In Part I and also in standard procedures sections of Part II Mr. Zejda demonstrates thorough familiarity with the subject. My only criticism here is that astrophysics and computer science aspects should not be confused in the review. Similarly, atmospheric and interstellar extinction do not depend on binary structure and their inclusion in the code is a matter of convenience and not physics. Clear distinction should be made between asynchronous rotation effect on shape and mere migration period of any spots. Generally, a solution is only as good as its underlying model and no programming tricks are going to improve that. Thus Wilson-Devinney method and PHOEBE would occupy the same position in a review for astrophysicists, while admittedly the latter code was more user friendly. Ordering of the review according to the astrophysical complexity of the underlying models would result in a more transparent picture. Despite this minor flaws, Part I arguably constitutes the most complete review of the software available for light curve synthesis and/or analysis.

Own work described in Part II concernes of ephemeris, photometric observations spectroscopic analysis and system solution. Mr. Zejda **analysis of ephemeris** from old eclipse data is remarkable by its scope and thoroughness. I commend use of orthogonal ephemeris coefficients on p. 59. Due caution is also exercised by the author in his discusion of Eq. 4.8. However, I remain unconvinced by the decaying oscillation interpretation of period variations and long term predictions in a system with a history of sharp changes. Note large deviations from this trend in 1990's. In this regard Fig. 4.6. should demonstrate observed values to evaluate validity of the fitted trend.

Generally, Mr. Zejda reduction of **photomeric data** is thoughtful. The Principal Component method of Mikulas'ek proved excellent tool for combination/detrending of various photometric runs. However, I do not understand wide discrepancy between Fig. 5.2 displaying scatter of order 0.05 Mag in maximum with the declared accuracy 0.002mag. Is that the price paid for ignoring delta scuti oscillations? Also, the author took care to remove interference from the visual companion (ADS9706B), where applicable.

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* Note use of an apostrophe ' for a generic diacrytic sign.

Many graduate students suffer from a think big or, more aptly, think grandiose syndrome. On the contrary, Mr. Zejda well informed remark that, for CCD photometry of his bright target, small instruments are the best (Sects 5.3 & 5.4.3), reveals his expert understanding of the error sources. On p. 79 the author notes some evidence of possible multi-modal oscillations. Why they remained unstudied? Puszzling observation of pulsations during total primary eclipse (Sect. 5.5.2.1) calls for physical explanation. Much information of astroseismic importance remained ignored in this way, while scatter in the data used for system modelling increased artifficialy. Except for pulsations and circumstellar matter/accretion disc interference, Mr. Zejda light curves are of very good quality and suitable for detailed analysis of TW Dra.

Mr. Zejda **spectroscopic analysis** od TW Dra is based on data obtained from several observers, notably Drs. S'lechta and R'ezba. Reductions were performed by himself. Similarly to his analysis of photometry, Mr. Zejda exercised great care in analysis of spectroscopy. The author made effort to reduce data by 3 independent methods: computer-aided hand-and-eye method, by CCF and, most notably, by spectra disentangling KOREL method of Hadrava. Clearly, the latter method performed the best. This is demonstrated both in reduced component cross-talk yielding larger extrema, and during cross over, where only disentangling yields any useful result. Further strength in this procedure stems from explicit account of the telluric lines and author selection of the suitable lines of both components from synthetic spectra and from analysis of result uncertainities by simulations involving solutions with a subset of fitted parameters.

Most important part of the thesis is devoted to **modelling** of observations and solving for system parameters. From p.30 I understand Roche geometry is not yet fully integrated with
FOTEL. Hence present use of FOTEL for modelling of semi-detached system TW Dra sounds to me like abuse of the otherwise well-proven code. The elipsoidal geometry is good approximation of shape but ignores asymetry of gravity darkenning, thus introducing some unphysical 'negative' reflection effect and also, distorts limb darkening. Thus FOTEL results deviate from those of Wilson-Devinney/PHOEBE by many standard deviations. However, WD model is well suited for TW Dra , hence Mr. Zejda results from PHOEBE should be reliable and his claimed parameter errors as small as 1-2% seem to me realistic. This impression is further supported by his analysis of performance of different methods on Baglow data. Systematic shift between WD and ellipsoidal model is best seen in orbital inclination.

I spotted a small number of **minor editing errors**. In Eq. 2.5 the closing bracket is ill positioned. The LHS of Eq.2.2 should be divided by I_{\lambda}(1). On p.27 references to equation Eq.(2.37) and ff. seem mislabelled. In Tables 3.1 and 3.2 symbols D and d supposedly meaning external/internal contact intervals remain unexplained. Notation in Eq. 4.1., 4.2 and 4.3 is mutually inconsitent thus hampering comparison of quadratic terms. On p.83 in description of Table 5.4 the comment on differential photometry is redundant as all tabulated data are differential by their very nature. In Fig. 6.3 fitted RV curve for the secondary component is missing. Unless convinced otherwise, I consider quoted from literrature Fig. 7.5 as 'an artists impression' and not reality. I see there no trace of powerful shock waves expected in similar stream collisions (see e.g. Acta Astron. 37, 141).

My main **criticism** concerns with what is not in the thesis. In Sect. 1.2. the author explains aptly why modern studies of eclipsing binaries are important. Yet given his excellent data and accurate system solution, author pursues none of the recommended lines of study from Sect. 1.2. Given Kusakin et al (2001) discovery of delta Scuti oscillations and their importance for astro-seismology author should devote more time to their detailed study (e.g. multiple modes, time evolution of amplitude and frequency). In Sect.6.5 photometric parralax of the visual companion is compared to the trigonometric

one. Yet this procedure is not repeated for the target eclipsing component TW Dra itself, using the model solution just derived. The photometric parralax from Mr. Zejda solution should be 2% accurate and relatively free of systematic errors while Hipparcos yields errors over 10%. Compared to the total work performed, these issues require only little extra effort. Fortunately this shortcoming is likely to be remedied by the author's participation in the 2008 campaign on TW Dra with the well defined astrophysical aim.

In general, Mr. Zejda did not invent any particular method for analysis of eclipsing binaries, yet his choice of tools and their application is expert. Arguably, some methods employed by Mr. Zejda, namely the Principal Component and KOREL methods, respectively by Mikulas'ek (2007, thesis Sect. 5.5.1) and Hadrava (2004 and references there, thesis Sect. 6.3.3), constitute state-of-art methods for their purposes. Also, Mr. Zejda exercised great care in analysis of his results quality, running special simulations and cross-checking different sets of own and literrature data. Thus his error estimates of order 1%-2% of the final stellar radii and masses to me appear both credible and impressive. The comparison of results obtained for the same data (of Baglow) by different methods/autors yields insight on systematic errors (Table 7.4 and text). Mr. Zejda observations and derived from them values of parameters constitute new scientific result as they expand the number of Algol systems studied with such a precision to a dozen or so (thus an increase by over 5%). The cumulative effect of new data on algol systems is bound to produce new new understanding of the late phases of Case B mass exchange in close binary stars. The amount of work the author put into his thesis, both in his search of historical sources (270 references), own observations (near 50 000 points !) and their reductions is outstanding. Mr. Zejda appears in full control over his data. From my limited experience his effort compares to that of P.Martinez, who spend a third part of his time in UCT graduate school at the telescope. One may note that apart from the thesis Mr. Zejda (co-)authored 57 papers quoted over 100 times. While many of them are just short communiques in IBVS, a handful constitute large articles in the most respected international astro-journals.

Observations and solution for binary parameters of an eclipsing system constitutes a conventional problem in astronomy. For the particular system TW Dra Mr. Zejda worked it in an expert way, attaining the precision reached in only about 10 groups worldwide. He is already an experienced observer with very good knowlege of advanced photometric and spectroscopic methods. Mr. Zejda demonstrated ability to collaborate with different groups and to knowlegably handle large amounts of data. He is a very hard working person, too. His thesis was prepared under tuition of Prof. Marek Wolf. In my opinion now Mr. Zejda is sufficiently qualified to work on his own as a post-doc. **Summarising**, science in the reported work is suitable for a thesis in astronomy while the amount of work by Mr. Zejda largely exceeds requirements. Thus I am fully confident to recommend to Mathematics-Physics Department of Charles University to proceed with processing of Mr. Zejda thesis.

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