Evidence for Rapid Variability in the Multiple System 68 u Her

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1 The Project 68 u Her

The eclipsing binary 68 u Herculis (HD 156 633, HR 6431, $\alpha_{2000} = 17^{\rm h}\,17^{\rm m}\,19\overset{\rm s}{.}6$, $\delta_{2000} = +33^\circ\,06'\,00''$, $m_V = 4.8$) is a well studied target on the Northern sky. Over the last century several photometric and spectroscopic campaigns have been undertaken to improve our understanding and the description of this binary system. 68 u Her is a semi-detached system whereby the secondary fills its Roche-lobe and whereby the components revolve in a circular orbit with a seemingly stable period of about $P_{\rm orb} = 2\overset{\rm d}{.}051026$ days, e.g. [1, 2, 3]. The spectral types of the components of the SB2 system are B2IV (primary) and B8 or B9 (secondary) [3].

Variations in the light-curves and line-asymmetries have been reported. These are interpreted by some authors as an effect of the presence of interstellar matter [4], while others [5, 3] explain them in terms of intrinsic variations, given that the primary is located in the instability strip of the β Cephei variables. The intrinsic variability has not yet been studied in detail.

We present the preliminary results of the analysis of a large dataset of spectroscopic observations of 68 u Her which have been gathered over the last 10 years using 5 different telescopes at 4 different observatories. Two different observing strategies were followed. The first is a long-term (1994-2005) monitoring of the target to study the binary system carefully with the aim to solve open questions such as uncertainties concerning the circularity of the orbit and the presence of apsidal motion. Secondly, in the framework of a systematic study of line-profile variable early-type B stars in close binary systems with the aim to study tidal effects on the pulsational behavior, time-series of high-resolution spectra where obtained during consecutive nights in

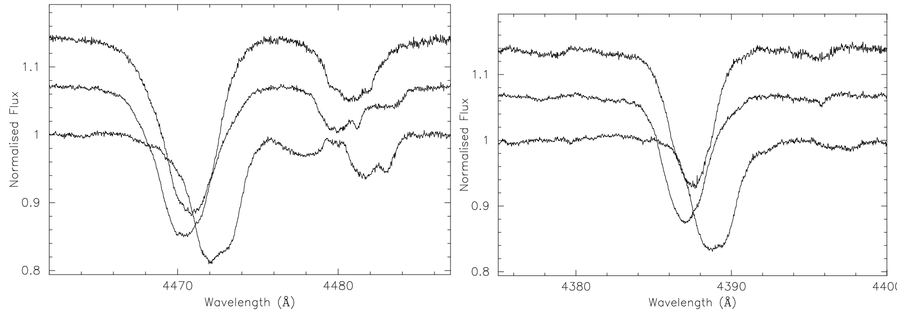

Fig. 1. A randomly chosen set of data for 68 u Her obtained with the SOFIN spectrograph at the NOT telescope. The profiles of the He I 4471.500 Å and Mg II 4481.136 Å lines (left) and the He I 4387.929 Å profiles (right). The spectra are offset for clarity

1996 and 2003. Table 1 gives a logbook of the observations. The spectra of the long-term program are mainly low-resolution spectra ($R < 20000$) centered on the H_α region, while the time-series are échelle spectra with $R \sim 50000$.

Table 1. Journal of the new data of 68 u Her. The last three columns denote the number of available RV measurements of primary and secondary, and the wavelength resolution, respectively

Nr.	Observatory	Telescope/Instrument	HJD interval (−2400000)	♯ RVs comp1	♯ RVs comp2	$\Delta\lambda$ (Å)
1	Ondřejov	2m/Reticon spectr.	49476-51708	34	18	0.25
2	KPNO	0.9m/spectrograph	50130-50604	65	22	0.09
3	DAO	1.22m/spectrograph	50222-50824	44	19	0.15
4	DAO	1.83m/spectrograph	50592-50711	18	12	0.139
5	Ondřejov	2m/CCD spectr.	52303-53464	36	17	0.25
6	ORM	1.56mNOT/SOFIN	52795-52806	175	105	0.02

Ondřejov, Czech Republic; KPNO: Kitt Peak National Observatory, Arizona, US; DAO: Dominion Astrophysical Observatory, Victoria, Canada; ORM: Observatorio del Roque de los Muchachos, La Palma, Spain

2 The Binary System

We selected several absorption lines for the determination of radial velocities (RV) of primary and secondary components. The contribution of the secondary was only prominent enough in the Si II 5055.984 Å, He I 6678.154 Å and Mg II 4481.136 Å lines. Values of the RVs of the secondary could only

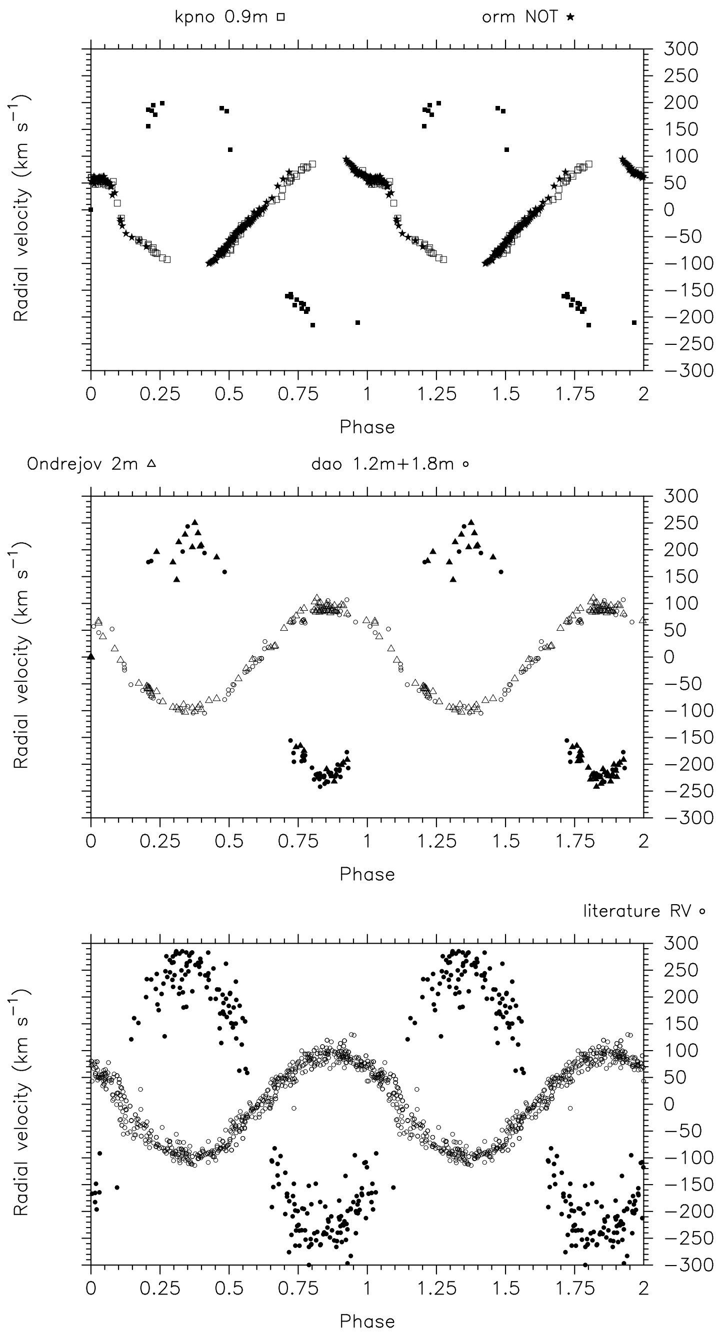

Fig. 2. Phase plots of the RV calculated from the high-resolution KPNO and NOT data (top), from the low-resolution DAO and Ondřejov data (middle) and from the RV found in the literature. ($P_{\rm orb} = 2\overset{\rm d}{.}0510354$ and phase=0 at $T_0 = 2450343.24$)

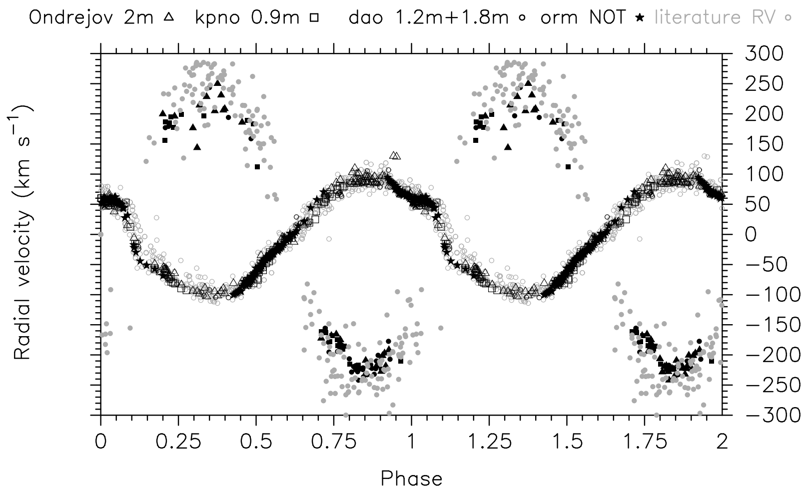

Fig. 3. Phase plot of both the new RV and the RV found in the literature ($P_{\mathrm{orb}} = 2\overset{\mathrm{d}}{.}0510354$ and phase=0 at $T_0 = 2450343.24$)

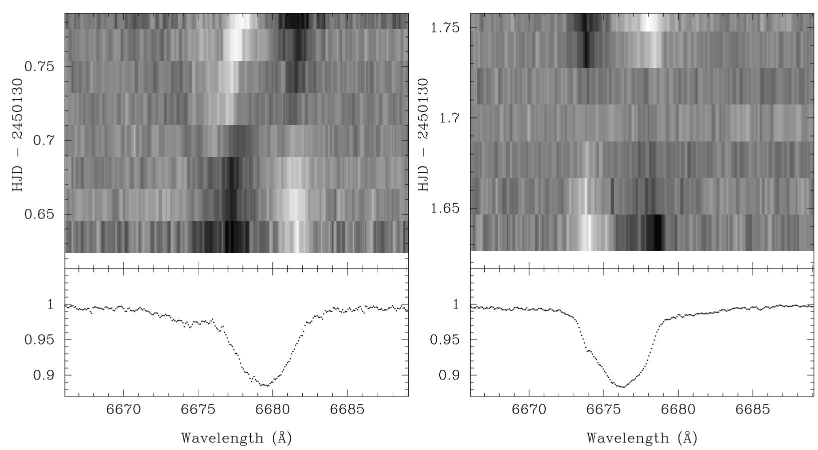

Fig. 4. Gray-scale figures showing the line-profile variability of the He I 6678.154 Å profile of 68 u Her in time during 2 subsequent nights in February 1996 (HJD 2450130 and 2450131). The KPNO spectra are plotted with respect to the nightly average profile, which is given at the bottom of each figure

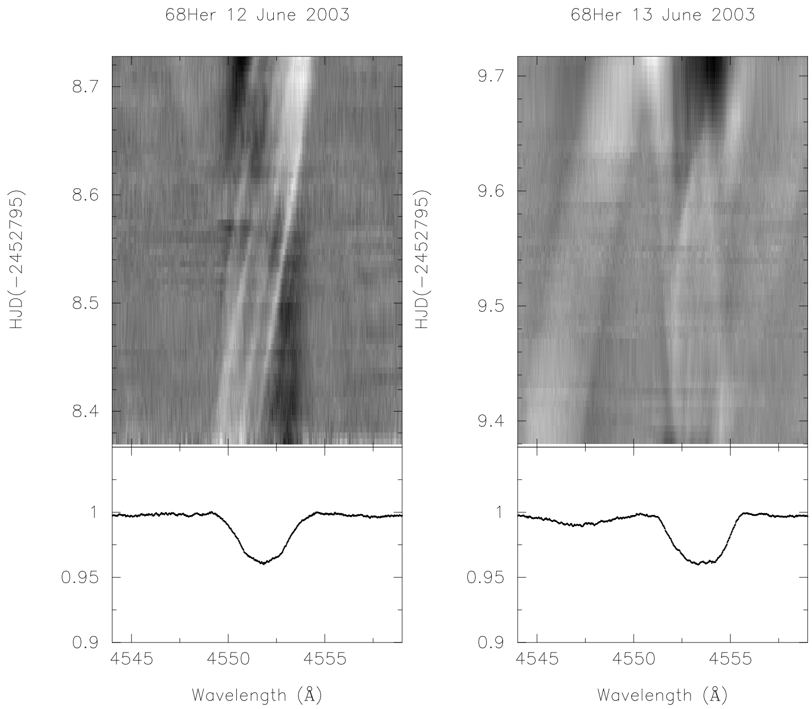

Fig. 5. Similar figure as Fig. 4 but for the SOFIN spectra obtained during two nights in June 2003 (HJD 2452803 and 2452804).

be derived at phases near elongation, when both profiles were separated. The RV were derived from the first normalized velocity moment $\langle v \rangle$, e.g. [6], using variable integration boundaries. A selection of profiles is given in Fig. 1. We present here only the RV calculated from the He lines. We enlarged our sample of RV with the available RV from the literature [7, 8, 9, 10, 11, 4, 3]. Most of these older values were obtained from photographic plates.

The analysis of the RV was carried out using the FOTEL code [12]. The results are presented in Figs. 2 and 3. On high resolution spectra the Rossiter effect [13] is clearly visible, while on the old data, mostly from photographic era, it is buried in noise – see Fig. 2 upper and lower panels.

The split of the data into three subsets in time indicates a significant period increase. The rate is small, typical for Algols at the late stages of the mass transfer. The solution with non-zero dP/dt gives a slightly larger r.m.s. error than that for a constant period. However, this might be related to the phases affected by the rotational effect.

All solutions invariably indicate zero eccentricity, a problem that in case of 68 u Her has been discussed for many decades.

3 Rapid Variability

Several time series of spectra of 68 u Her were secured. The preliminary analysis has shown that rapid line-profile variability could be detected only on high resolution spectra. Thus, time series obtained at KPNO and ORM Observatories were analyzed. The results are presented in Fig. 4 and Fig. 5. The black and white bands show a pattern that is typical for non-radial pulsation (NRP) modes. This is the first firm evidence for the pulsations of the primary component of 68 u Her. In order to investigate the NRP further, a detailed line-profile analysis is required.

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