Long-term radial velocity monitoring of 26 bright galactic Cepheids

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Abstract

Between 2011 and 2014 we carried out radial velocity measurements of 26 bright galactic Cepheids (V > 11m), in order to identify previously unknown spectroscopic binaries among the program stars, and to determine or refine the orbital elements of the known binaries, if possible.

We used the 0.5 m RC telescope and a fiber-fed spectrograph of the Gothard Astrophysical Observatory of Eötvös Loránd University, Szombathely, installed in the fall of 2011. The spectrograph is the eShel system of the French Shelyak Instruments, with a resolving power of R = 11000 in the full optical region. Using dozens of metallic lines from the whole covered spectral range, we are able to measure radial velocities down to the precision of approx. +/- 100 m/s. Thanks to the portability of the spectrograph, we could carry out observations using the 1m RCC telescope at Piszkéstető Mountain Station of the Konkoly Observatory as well.

As of early 2014 we compiled precise pulsational velocity phase curves of 26 galactic Cepheids, including the first radial velocity measurements of V411 Aql. Based on our observations we identified the Cepheids V1344 Aql and FN Aql as members of spectroscopic binary (SB) systems. Our observations of AW Per and T Mon might contribute to more accurate orbital solutions for both systems.

Radial velocity monitoring of a large number of Cepheids will be essential in finding more long-period SBs among them. In practice, the orbital radial velocity variation of the Cepheid component is superimposed on the RV variations of pulsational origin. Beside space probe measurements, regular ground-based observations with sub-meter telescopes are excellent tools to follow the long term variability of binary systems in order to determine their orbital elements.

Data to be obtained with the Gaia astrometric space probe (launched on 19 December 2013) will certainly result in revealing many new spectroscopic binaries among Cepheids brighter than 13-14th magnitude.

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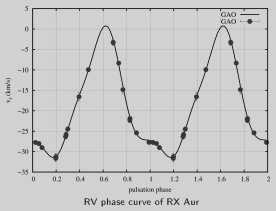
1. Introduction

Classical Cepheid variables are well known primary distance indicators owing to their the period - luminosity relationship.
According to Szabados (2003) more than 50% of the Cepheids are members of binary systems. Among others, the membership in such a system has an effect on the P-L relationship by affecting the brightness and colours of the Cepheid (Szabados et al., 2013).
Radial velocity monitoring of a large number of Cepheids will be essential in finding more long-period spectroscopic binaries (hereafter SB) among them. In practice, the orbital radial velocity (RV) variation of the Cepheid component is superimposed on the RV variations of pulsational origin. Beside space-based measurements, regular ground-based observations with sub-meter telescopes are excellent tools to follow the long term variability of binary systems in order to determine their orbital elements.
Between 2011 and 2014 we carried out radial velocity measurements of 26 bright galactic Cepheids ($V < 11$m), in order to identify previously unknown SBs among the program stars, and to determine or refine the orbital elements of the known binaries, if possible.

2. Observations

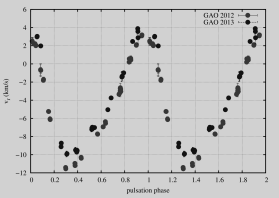
The echelle spectrograph of the ELTE GAO made by the French Shelyak Instruments (Thizy and Cochard, 2011) was installed in fall 2011. With the acquisition of the spectrograph it became possible to integrate spectroscopic measurements into the Hungarian astronomy and astronomical education and to start independent series of spectroscopic measurements of bright Cepheids.
Using dozens of metallic lines from the whole covered spectral range (430–840 nm), we are able to measure radial velocities down to the precision of approx. $\pm$ 100 m/s.
The exposure times were typically 900 sec and ThAr spectra were recorded in each hour during the night, before and after the spectra of the targets were taken. At the beginning and at the end of every night RV standards were measured to check the consistency of wavelength calibrations.
Data reduction was carried out with the standard tasks in IRAF. R = 11500 synthetic spectra chosen from the Munari et al. (2005) library were used to the cross-correlation of the observed and synthetic spectra. RV determination was done using the FXCOR task of IRAF, correlations were calculated between 487 and 655 nm, excluding Balmer lines, NaD and telluric regions.
Cepheids on our target list are possible binaries, e.g. RX Aur.



RV phase curve of RX Aur

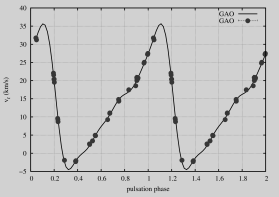
3. Results

V1344 Aql was one of the examined Cepheids in our program. We choose this star because there were signs of binarity based on earlier RV observations taken by Balona (1981) and Arellano Ferro (1984). Our observations taken in 2012 verify the presence of a second star beside the Cepheid. Our new RV data taken in 2013 imply that this system has a relatively short orbital period.



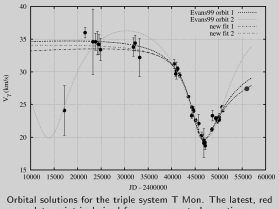
RV phase curve of V1344 Aql

AW Per is an another known multiple system in our target list, that contains a Cepheid variable. We measured new RV data in 2013 that can lead to a more accurate determination of orbital elements, examined simultaneously with the $O-C$ data. Three earlier orbital solutions to this system show that the orbital period is about 35 years.



RV phase curve of AW Per

In the case of the known triple system, T Mon the new gamma-velocity derived from our RV data taken in 2012 gives two new orbital solutions. The orbital elements were previously determined by Evans et al. (1999). They obtained two completely different solutions: with and without taking into account Frost's (1906) early RV data. Our new solutions are closer to the long period solution of Evans et al. (1999) and indicates several hundred years orbital period.



Orbital solutions for the triple system T Mon. The latest, red data point is derived from our recent observations

4. Gaia

The Gaia astrometric space probe of the European Space Agency was launched on 19 December 2013. The aim of the project is to create a 3D map of the Milky Way based on the motion of the stars.


Artist's impression of the Gaia spacecraft. Source: ESA.

Beside astrometric and photometric measurements, Gaia will also provide RV observations. The equipment for the RV observations on board of the space probe is a slitless spectrograph, the wavelength range of the instrument is between 845 and 872 nm. The resolving power of the spectrograph is 11500, about the same as the Shelyak eShel. The FoV is $0.22^\circ \times 0.39^\circ$. The selection of the appropriate wavelength range was important, because the interstellar absorption makes the stars even redder. Studies showed, that the Ca II triplet near 860 nm is optimal for RV determination (Perryman et al., 2001).
It will provide on average 120 spectra/star in 5 years of the operation. RV measurements will be carried out up to 15th magnitudes. The ground-based follow up observations are necessary, because of the limited possibility of continuous spectroscopic measurements of the space observatory. With our equipment, we are able to follow up the bright Cepheid targets of Gaia to obtain the long term RV variability.

References

Arellano Ferro, A.: 1984, *MNRAS* **209**, 481

Balona, L. A.: 1981, *The Observatory* **101**, 205

Evans, N. R. et al.: 1999, *ApJ* **524**, 379

Frost, E. B.: 1906, *ApJ* **23**, 264

Munari, U., Sordo, R., Castelli, F., and Zwitter, T.: 2005, *A&A* **442**, 1127

Perryman, M. A. C. et al.: 2001, *A&A* **369**, 339

Szabados, L.: 2003, *IBVS* **5394**, 1

Szabados, L., Anderson, R. I., Derekas, A., Kiss, L. L., Szalai, T., Székely, P., and Christiansen, J. L.: 2013, *MNRAS* **434**, 870

Thizy, O. and Cochard, F.: 2011, in C. Neiner, G. Wade, G. Meynet, and G. Peters (eds.), *IAU Symposium*, Vol. 272 of *IAU Symposium*, pp 282–283

Acknowledgement

The authors would like to thank Konkoly Observatory for using 1m RCC telescope and its infrastructure. The project has been supported by City of Szombathely under Agreement No. S-11-1027. L. Szabados thanks also ESTEC for supporting his work under Contract No. 4000106398/12/NL/KML.