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Tipsy pulsation of classical Cepheids – lessons from space photometry

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Abstract. Space photometric data of the Kepler Cepheid, V1154 Cygni, and those of SZ Tauri (*MOST* photometry) indicate that classical Cepheids are not strictly regular pulsators. Cycle-to-cycle period changes and variations in the shape of the light curve are revealed from the continuous photometry covering 6 cycles of SZ Tau pulsation and several hundred pulsation cycles of V1154 Cyg. To make the situation more interesting/complicated, the *MOST* light curve of RT Aurigae (a Cepheid pulsating in the fundamental mode) shows stellar oscillations in a highly repetitive manner.

1 Introduction

Classical Cepheids are the archetype of the regular radial pulsators. However, recently there are several pieces of photometric evidence at odds with this simplistic viewpoint. Folded light curves of small-amplitude Cepheids (possibly overtone pulsators) show wider scatter than their normal amplitude siblings performing fundamental-mode oscillations (see Fig. 1) [1]. Moreover, slightly excited nonradial modes were revealed in the pulsation of Magellanic Cepheids from the OGLE data base [2].

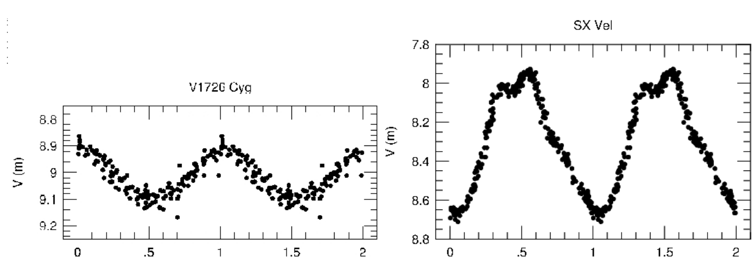

Fig. 1. The pulsation of low-amplitude Cepheids (e.g., V1726 Cyg, left) is more unstable than that of Cepheids pulsating in the fundamental mode (SX Vel, right) even when using the accurate (instantaneous) value of the pulsation period (data from [1])

The original *Kepler* field contains only one genuine Cepheid variable: V1154 Cygni [3]. The extremely precise photometry of *Kepler* space telescope was used for directly revealing fluctuations in the light curve and the pulsation period of V1154 Cygni [4].

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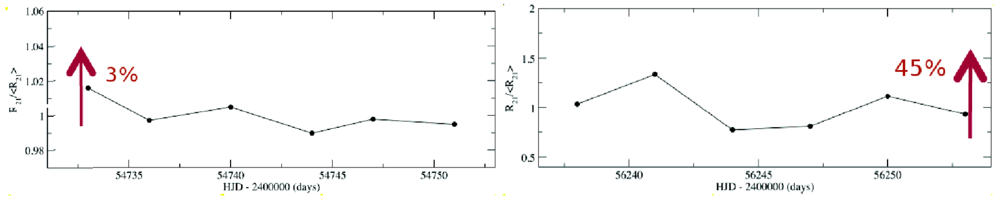

Fig. 2. Behaviour of the Fourier amplitude ratio, R_{21} of RT Aur (left) and SZ Tau (right)

2 *MOST* photometry of two Cepheids: SZ Tauri and RT Aurigae

To confirm that the case of V1154 Cyg is not unique, a proposal was submitted for *MOST* observations of other bright Cepheids. Two targets were observed: the first-overtone pulsator SZ Tauri and RT Aurigae, a Cepheid pulsating in the fundamental mode.

The light curve of both Cepheids is unstable to some degree, and the overtone pulsator, SZ Tau shows a larger amplitude variance with pulsation cycle. For qualitative characterization of the jitter, the light curves have been decomposed using the Fourier parameters introduced by [5]. Both the amplitude ratio, R_{21} (Fig. 2) and the phase parameters ϕ_{21} and ϕ_{31} fluctuate stronger in the overtone pulsator than in the fundamental-mode one.

In addition to the fluctuations in the shape of the light curve, the pulsation period also changes from cycle-to-cycle as testified by the $O-C$ diagrams. Again, the wobbling is stronger for the overtone pulsation [6].

3 Conclusion

The tipsy pulsation of classical Cepheids is an unexpected behaviour that calls for a theoretical explanation. An immediate hypothesis involves convection on the stellar surface [7].

Quite recently, a similar behaviour was found in the radial velocity phase curves of four Cepheids of rather different nature (pulsation mode and period): ℓ Car, QZ Nor, RS Pup, and V335 Pup [8].

Further accurate photometric observations of Cepheids are necessary. Future space photometry by *Kepler* K2, *BRITE*, *Gaia*, *TESS*, and *PLATO* will facilitate a better characterization of the jitter in the pulsation of classical Cepheids.

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