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## The magnificent past of RR Lyrae variables

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**Abstract.** We briefly review the results obtained by using the times of maximum brightness of RR Lyr variables. They cover more than 120 years and have been used to study the evolutionary changes of the pulsational periods, the different shapes of the Blazhko effect among galactic RRab stars, and the interplay between pulsational and Blazhko periods in the eponym of the class, RR Lyr. The data are stored in the GEOS database, continuously fed by contributions from professional and amateur astronomers.

### 1. Introduction

The history of the observations of RR Lyr variables started in the XIXth century, more than 120 years ago. The variability of RR Lyr itself was discovered on the photographic plates of the *Henry Draper Memorial* by Mrs. Williamina P. Fleming (Pickering et al. 1901). The first measurement comes back to July 20, 1899, the first time of maximum brightness ( $T_{\max}$ ) to September 23, 1899. The list of  $T_{\max}$  recorded from 1906 July 15 to August 25 on RW Dra clearly shows variations of amplitude and phase (Blazhko 1907). Shapley (1916) noted the same variations in the data of RR Lyr itself: this phenomenon was later named *Blazhko effect* in the astronomical literature.

The very long time baseline of available data combined with the short period of RR Lyrae variables offer an unique opportunity to look at their past as a treasure of valuable information. At this purpose, the amateur/professional association Groupe Européen d’Observations Stellaires (GEOS) has built a database aimed to gather all the published  $T_{\max}$  values (Le Borgne et al. 2007). It also promotes the regular monitoring of RR Lyrae variables by means of own-made instruments and observing time at robotic telescopes.

### 2. Evolutionary changes

The long time baseline allowed us the opportunity to study period changes due to stellar evolution (Le Borgne et al. 2007). Most of the 123 scrutinized RRab stars does not show any significant period variation. This reflects the fact that

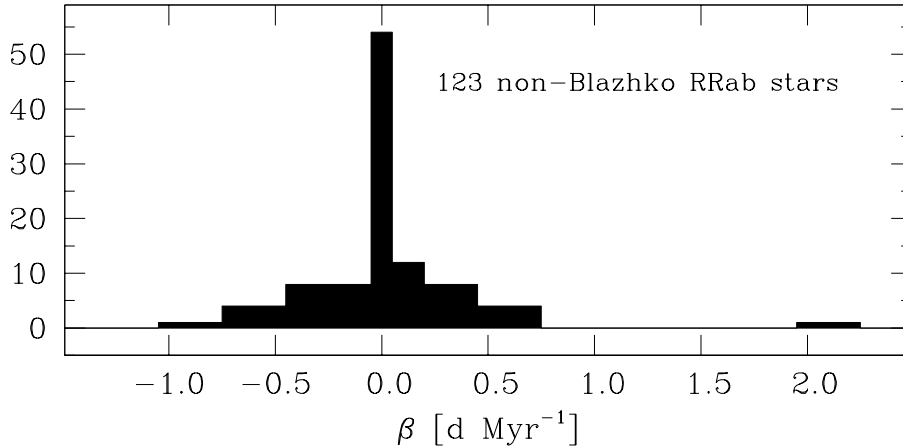


Figure 1. Distribution of the rates of period changes. The extreme positive value is that of SV Eri

the rapid evolution is confined in short evolutionary phases. Notwithstanding this, we could put in evidence period increases in 27 stars and decreases in 21 ones (Fig. 1). The median values of the rates are  $+0.14 \text{ d M yr}^{-1}$  and  $-0.20 \text{ d M yr}^{-1}$ , respectively. The order of magnitude of these rates is that expected from evolutionary models and being common to a large number of stars it strongly supports the evolutionary origin.

We used stars not showing the Blazhko effect to study the evolutionary changes. Or, at least, not showing an appreciable effect for the ground-based observations. Indeed, nowadays space-based time series are detecting very small Blazhko effects, as in the case of V350 Lyr (Benkő & Szabó 2015). Even if present in our sample, these small effects are not able to mask the large amplitude evolutionary changes. Several case of erratic changes were observed, both increasing and decreasing the period. They should be the result of particular temporary instabilities rather than be considered as representative of a particular evolutionary stage. It was also noticed a slight excess of RR Lyr stars showing period decreases (i.e., stars on blueward evolutionary tracks). However, further studies on a larger sample suggested that the excess was mainly due to the limited statistics (Vandenbroere et al. 2014).

### 3. The different shapes of the Blazhko effect

We used the GEOS database to study the Blazhko effect of galactic RRab stars, too (Le Borgne et al. 2012). The closed curves representing the Blazhko effect are constructed by plotting the magnitudes at maximum ( $V_{\max}$ ) vs. the  $O - C$  (*observed minus calculated*)  $T_{\max}$  values. We could emphasize some clear observational facts: *i*) the same value of the Blazhko period is observed at different values of the pulsation periods; *ii*) different values of the Blazhko periods are observed at the same value of the pulsation period; *iii*) the closed curves describing the Blazhko cycles have different shapes. These curves have often the

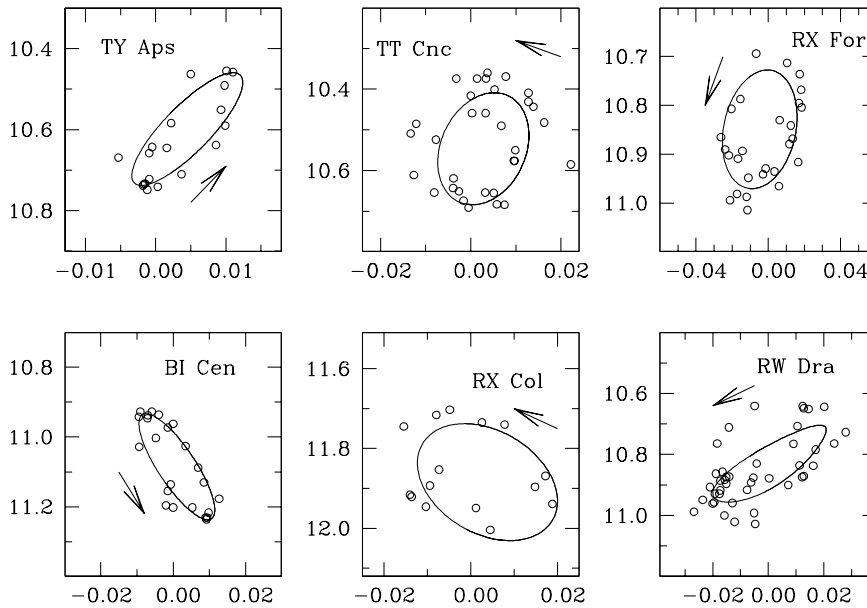


Figure 2. The full rotation of the axis in stars running counterclockwise the closed curves in the O-C (abscissa, in days) vs.  $V_{\max}$  (ordinate) plots.

shape of a potato, but other exotic contours are observed; *iv*) both clockwise and counterclockwise are possible for closed curves with similar shapes.

All these facts lead to a variegated group of behaviours. For instance, the brightest maximum could correspond to the most negative phase shift in some stars and to the most positive one in others. We could observe a full rotation of the *Blazhko potato* in the sample of galactic RRab stars. Figure 2 shows the case of stars running counterclockwise. The regular survey of RRab stars is undergoing using both amateurs' observatories and the robotic TAROT telescopes (Klotz et al. 2008, 2009; Le Borgne et al. 2012).

#### 4. The vanishing of the Blazhko effect of RR Lyr

The analysis of the  $T_{\max}$  epochs listed in the GEOS database allowed us to reconstruct the changes in the pulsational period of RR Lyr. We could establish the existence of two states characterized by the pulsation over a “long” period (longer than 0.56684 d) and over a “short” one (shorter than 0.56682 d). We also determined the Blazhko period in several time intervals since 1910 and we verified how it changed while the two states alternated. The variations of the pulsation and Blazhko periods resulted completely decoupled, since the Blazhko period had just one sudden decrease from 40.8 d to 39.0 d in 1975 (Le Borgne et al. 2014). The current period is the shortest never measured, i.e., less than 0.5668 d.

Some years ago, two of us (J.F. Le Borgne and A. Klotz) planned and realized small, autonomous and transportable photometric instruments to make the ground-based survey of RR Lyr as effective as possible. They assembled

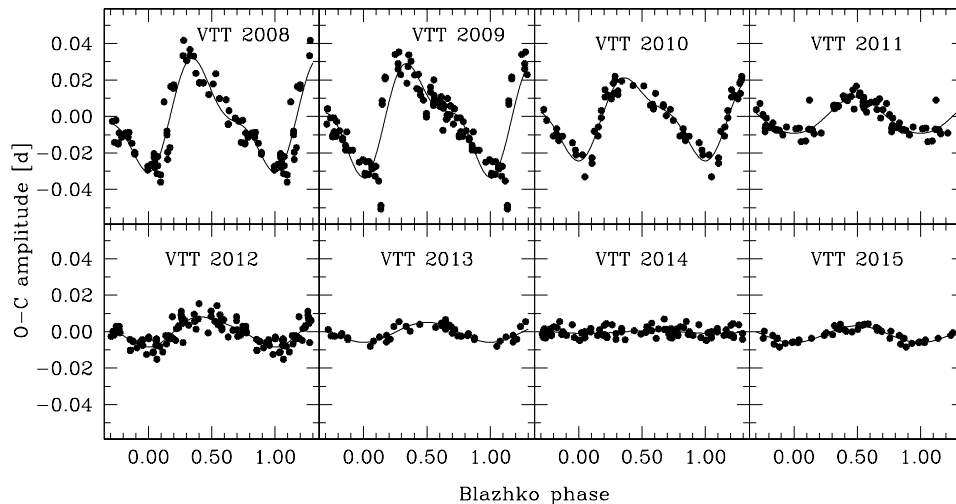


Figure 3. O-C values of RR Lyr folded with the Blazhko period

a commercial equatorial mount (Sky-Watcher HEQ5 Pro Goto), an AUDINE CCD camera (512x768 kaf400 chip) and a photographic 135-mm focal, f/2.8 lens with a field of view of  $2^\circ \times 3^\circ$ . They gave them the nickname VTTs for “Very Tiny Telescopes”. The regular recording of the  $T_{\max}$ ’s of RR Lyr started in 2008. Data from VTTs and *Kepler* have been extensively used to record the monotonic long-term decrease in the amplitude of the Blazhko effect. As a matter of fact, the Blazhko effect was hard to detect by looking at the maxima collected in 2014 only. However, the new  $T_{\max}$  collected with the VTTs in 2015 seem to show a slight increase in the amplitude of the O-C values (Fig. 3), a sign that the still unknown Blazhko mechanism is back at work.

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