# Blazhko Phenomenon

*The Impact of Large-Scale Surveys on Pulsating Star Research*
*ASP Conference Series, Vol. 203, 2000*
*L. Szabados & D. W. Kurtz, eds.*

# RR Lyrae: Analysis of 100 Years of Observations

B. Szeidl, Z. Kolláth

*Konkoly Observatory, P.O. Box 67, H-1525 Budapest, Hungary*

**Abstract.** Photometric observations of RR Lyrae obtained in the past one hundred years are reviewed and some important results are presented.

## 1. Introduction

At the beginning of this century Mrs. W. P. Fleming at the Harvard Observatory announced the discovery of a "short-period Cepheid" in Lyra (Pickering 1901), the first one outside a globular cluster. The discovery photographic plate was made just 100 years ago, on 1899 July 30. The star was named RR Lyrae and became the eponym of a group of stars with similar characteristics.

RR Lyrae has played a significant role in the study of pulsating stars and is one of the best observed variables. Immediately after its discovery a number of skilled variable star observers (among others, O. C. Wendell, E. Hartwig, E. Hertzsprung, H. v. Zeipel, C. C. Kiess) carried out visual measurements. The first thorough photographic observations were made by Martin & Plummer (1915). Prager (1916) was the first who became aware of the 41-d oscillation in the phase of the star's light maxima – a phenomenon that had been discovered by Blazhko (1907) in the behaviour of the light maxima of RW Draconis.

In his fundamental work, Shapley (1916) investigated the changes in the spectrum, period and light curve of RR Lyrae.[1] He wrote: "There can be no doubt that a real irregularity is present. An attempt was made to find a uniform period for the variations that would satisfy all the observations. This failed in part, perhaps because of insufficient data, but it seems that for the whole series the oscillation is roughly periodic with a varying amplitude." He obtained a secondary period of 41 d and an amplitude of 37 min for the time oscillation of the median magnitude of the ascending branch.

Subsequent to the early investigations a great number of visual and photographic observations were obtained by a good many observers. The first photoelectric observations were made by Walraven (1949) which were followed by others. Among these works the study by Preston, Smak, & Paczyński (1965) deserves particular attention. They carried out concurrent photoelectric observations of very high accuracy in three colours and spectroscopic observations.

[1] Since S. Blazhko was the very first to notice the periodic oscillation of the phase of the maxima in an RR Lyrae star, we refer to this periodic variation as the Blazhko effect. However, H. Shapley was the first who demonstrated that the phenomenon was accompanied by the periodic variation in the shape of the light curve and in the height of the maxima, and therefore the effect should perhaps be called the Blazhko–Shapley effect.

They pointed out that virtually all photometric and spectroscopic parameters were strongly variable over the 41-d cycles.

Babcock (1958) discovered that the magnetic field strength of RR Lyrae was variable. In a subsequent investigation Romanov, Udovichenko & Frolov (1987) pointed out that the mean field strength (over the pulsation cycle) depends on the phase of the amplitude modulation. This discovery may be relevant to the Blazhko effect that favours the oblique pulsator interpretation of the 41-d cycle.

## 2. The Investigation of Blazhko Effect at Konkoly Observatory

In the 1930s, L. Detre started a systematic investigation of RR Lyrae stars with Blazhko effect at the Konkoly Observatory. One of the best-studied stars was RR Lyrae itself. Between 1935 and 1950 more than 10 000 photographic observations were obtained with a 20-cm astrograph. Since 1950 photoelectric observations have been carried out with the 60-cm reflector at Budapest – in the beginning without filters, and afterwards in the *UBV* system. During three decades more than 34 000 observations were collected and these observations were supplemented by E. F. Guinan's recent Strömgren and H$\beta$ photometry (Balázs & Detre 1943; Szeidl et al. 1997).

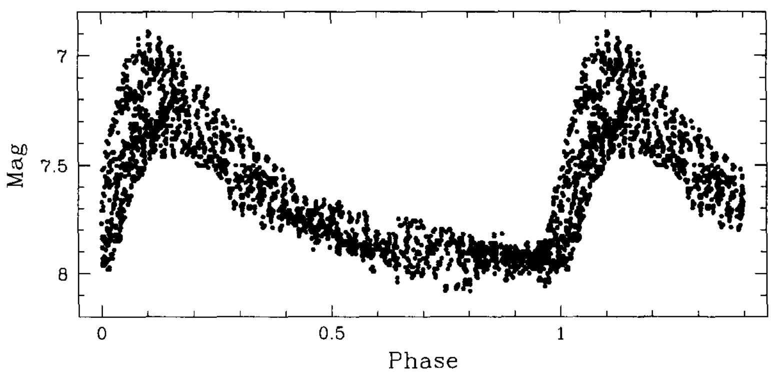


Figure 1. The folded photographic light curve of RR Lyrae from the years 1943–1945.

The Konkoly photoelectric observations were only obtained during the ascending branches and light maxima of the star, so they are not suitable for Fourier analysis. However, the changes in the amplitude of the light variation and in the shape of the maxima during one Blazhko cycle can well be studied. It is clear that the cycles of the amplitude modulation differ in both length and amplitude which means that the effect is not a strictly repetitive phenomenon. (Attempts at representing these variations by longer periods have failed.)

The photographic observations cover the light curve well at different phases of both the fundamental period and the Blazhko cycle (Fig. 1), and are suitable for Fourier analysis. The spectrum, the prewhitened spectrum and the spectral

https://doi.org/10.1017/S0252921100057894 Published online by Cambridge University Press

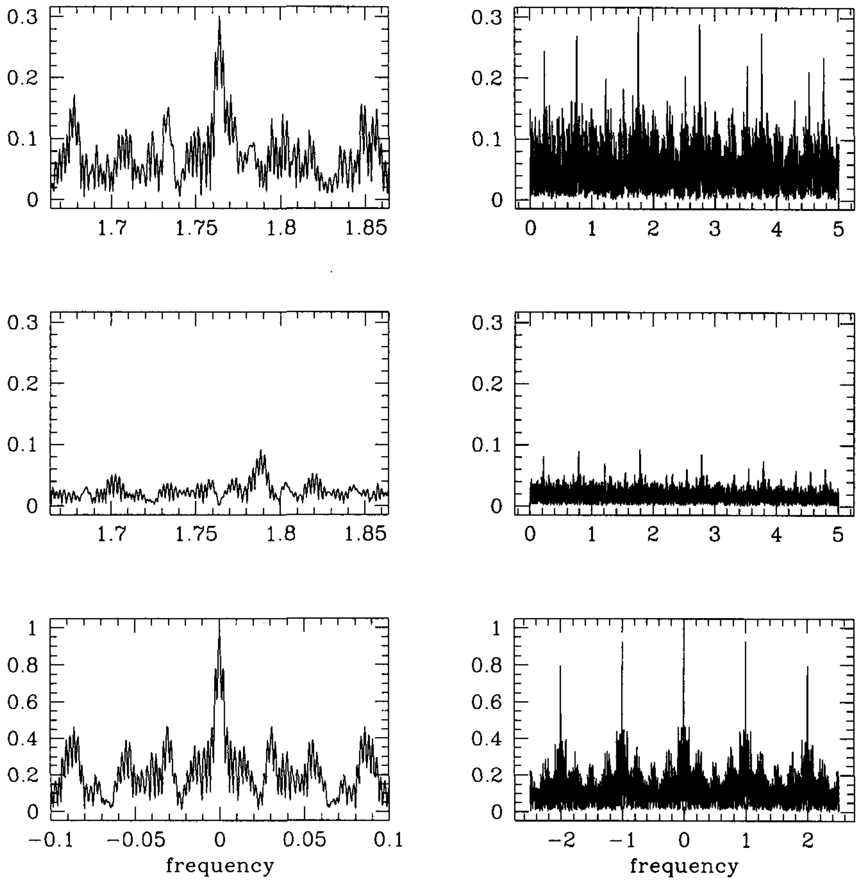


Figure 2. The spectrum (top), prewhitened spectrum (centre) and spectral window (bottom) for the 1943-1945 photographic observations.

window are shown in Fig. 2. The peaks of the frequencies $kf_0 \pm f_m$ ($k = 0$, 1, ...), where $f_0$ is the fundamental frequency and $f_m$ the Blazhko frequency, are present. The amplitudes of the $kf_0 + f_m$ components are significant while the amplitudes of the $kf_0 - f_m$ components are only marginal. Walraven's and Guinan's photoelectric datasets reveal a similar picture and show that the amplitudes of the $kf_0 + f_m$ frequencies are larger than the amplitudes of the $kf_0 - f_m$ frequencies.

## 3. Long-Term Behaviour

The regular observations of the ascending branch and maximum of RR Lyrae enabled us to study the long-term changes of the Blazhko effect. Its amplitude has shown variations on a time scale of years and in some years the 41-d Blazhko

https://doi.org/10.1017/S0252921100057894 Published online by Cambridge University Press

cycle has almost disappeared. Preston et al. (1965) mentioned that it was barely noticeable in 1963, and we observed a similar decrease in the amplitude of the modulation in 1967 and 1971. A discussion of all the photographic and photoelectric observations led to the discovery of a four-year cycle in the Blazhko effect of RR Lyrae (Detre & Szeidl 1973). A similar decrease of the amplitude of the Blazhko effect was observed in 1975, which confirmed our previous results. It was also pointed out that at the end of these four-year cycles a phase shift of either $\pi/2$ or $-\pi/2$ radians always takes place in the phase of the Blazhko cycle (Szeidl 1976).

The fundamental period has been subject to strong variation. The $O-C$ diagram (Fig. 3) has been constructed by using all the available observations. No regularity can be noticed in the changes of the fundamental period. The waves of the $O-C$ diagram have probably come into being by accumulating random fluctuations in the period.

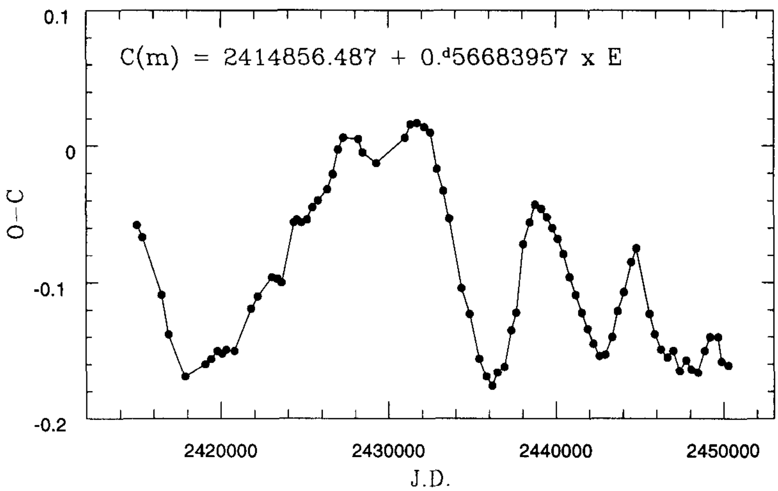


Figure 3. The $O-C$ diagram of the fundamental period of RR Lyrae.

## 4. A Comparison with other Blazhko Stars

Hitherto several RR Lyrae stars with Blazhko effect (RS Bootis: Nagy 1998; AH Camelopardalis: Smith et al. 1994; AR Herculis: Borkowski 1980, Smith et al. 1999; RV Ursae Majoris: Kovács 1995) have been thoroughly investigated and mathematical descriptions of their light variation given. In general, the $kf_0+jf_m$ ($k=0,1,2,...$; $j=-1,0,+1$) frequency solution satisfies the observational accuracy of the data more or less, but usually there is extra scatter present in the data which cannot be accounted for in the Fourier description. The $j\geq 2$ components are not significant, if present at all, and the assumption of

https://doi.org/10.1017/S0252921100057894 Published online by Cambridge University Press

the equidistant frequency spacing in the triplets seems to be valid for all the significant harmonics.

It is worth mentioning that all the well-observed RRab stars showing Blazhko effect in the Galactic field exhibit both strong amplitude and phase modulation.

**Acknowledgments.** This work was supported in part by the grants OTKA T-026031 and T-030955.

## References

Babcock, H. W. 1958, ApJS, 3, 141

Balázs, J. & Detre, L. 1943, Mitt. Sternw. Budapest, No. 18

Blazhko, S. 1907, Astron. Nachr., 175, 325

Borkowski, K. J. 1980, Acta Astron., 30, 393

Detre, L. & Szeidl, B. 1973, in IAU Coll. 21, Variable Stars in Globular Clusters and Related Systems, ed. J. D. Fernie (Dordrecht: Reidel), 31

Kovács, G. 1995, A&A, 295, 693

Martin, C. & Plummer, H. C. 1915, MNRAS, 75, 566

Nagy, A. 1998, A&A, 339, 440

Pickering, E. C. 1901, Harvard Circ., 54

Prager, R. 1916, Sitzb. Ak. Berlin, 8, 216

Preston, G. W., Smak, J., & Paczyński, B. 1965, ApJS, 12, 99

Romanov, Yu. S., Udovichenko, S. N., & Frolov, M. S. 1987, Pis'ma Astron. Zh., 13, 69

Shapley, H. 1916, ApJ, 43, 217

Smith, H. A., Barnett, M., Silbermann, N. A., & Gay, P. 1999, AJ, 118, 572

Smith, H. A., Matthews, J. M., Lee, K. M., Williams, J., Silbermann, N. A., & Bolte, M. 1994, AJ, 107, 679

Szeidl, B. 1976, in IAU Coll. 29, Multiple Periodic Variable Stars, ed. W. S. Fitch (Budapest: Akadémiai), Vol. 1, 133

Szeidl, B., Guinan, E. F., Oláh, K., & Szabados, L. 1997, Comm. Konkoly Obs. No. 99

Walraven, Th. 1949, Bull. Astr. Inst. Netherl., 11, 17

## Discussion

*Mike Jerzykiewicz*: How many terms did you use to prewhiten the data for frequency spectra shown in the middle panels of your figures?

*Béla Szeidl*: We prewhitened our data with the fundamental frequency and its first five harmonics.

*Merieme Chadid*: What do you think about the origin of the 4-year-cycle of amplitude variation in RR Lyrae?

*Béla Szeidl*: I think that the four-year cycle can be identified with a solar-like magnetic cycle.

https://doi.org/10.1017/S0252921100057894 Published online by Cambridge University Press