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The Blazhko Project: Unravelling the Mysteries of Amplitude Modulation

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Abstract. A large fraction of the pulsating RR Lyrae stars shows a periodic amplitude and/or phase modulation, denoted the Blazhko effect. Nearly a century after its discovery, this phenomenon remains a mystery. The Blazhko Project is an international collaboration focused on a better understanding of the Blazhko effect. Through a cross-fertilization of observational and theoretical expertise, progress in this field is guaranteed.

1. The Blazhko Effect

In 1907 the Russian astronomer Sergei Nicholaevich Blazhko discovered that the times of maximum of the RR Lyrae star RW Dra could not be described by a single period. He detected an additional cyclic variation of 41.6 days (Blazhko 1907). Soon thereafter, similar observations were made in other RR Lyrae stars. Shapley (1916) found that RR Lyrae itself, the eponym and brightest star of the class, displayed a secondary period of about 40 days. This period was later refined to about 40.8 days (see, e.g., Fringant 1961). The 'anomalous' stars showed cyclic amplitude and/or phase modulation of their light variation, resulting in clear changes in the light curve shape, over a period of typically tens to hundreds of days. As an example, Figure 1 shows the light curve variations of RR Lyrae over the modulation cycle from observations made in 2003-2004. Spectroscopic data and radial velocity curves of Blazhko stars also show a modulation with the so-called Blazhko period. For his merits as an astronomer, Blazhko not only got a Moon crater named after him, but also a phenomenon which has been puzzling observers and astrophysicists for almost a century now, perhaps the greatest challenge to stellar pulsation theory.

Just like the Cepheids, the pulsating RR Lyrae stars obey a period-luminosity relation which makes them important astronomical tools for distance determination. With their main pulsation (period between 0.2 and 1.1 day) being purely radial, they come in different flavors. The RRab stars pulsate in the radial fundamental mode, have the longer periods, and rather asymmetric light curves with amplitudes often exceeding one magnitude. Their pulsations are highly nonlinear and can only be described by taking into account multiple harmonics of the main frequency. The shorter-period RRc stars pulsate in the radial first overtone mode and have more sinusoidal light curves with lower amplitudes. The RRd stars are double mode pulsators, combining both radial

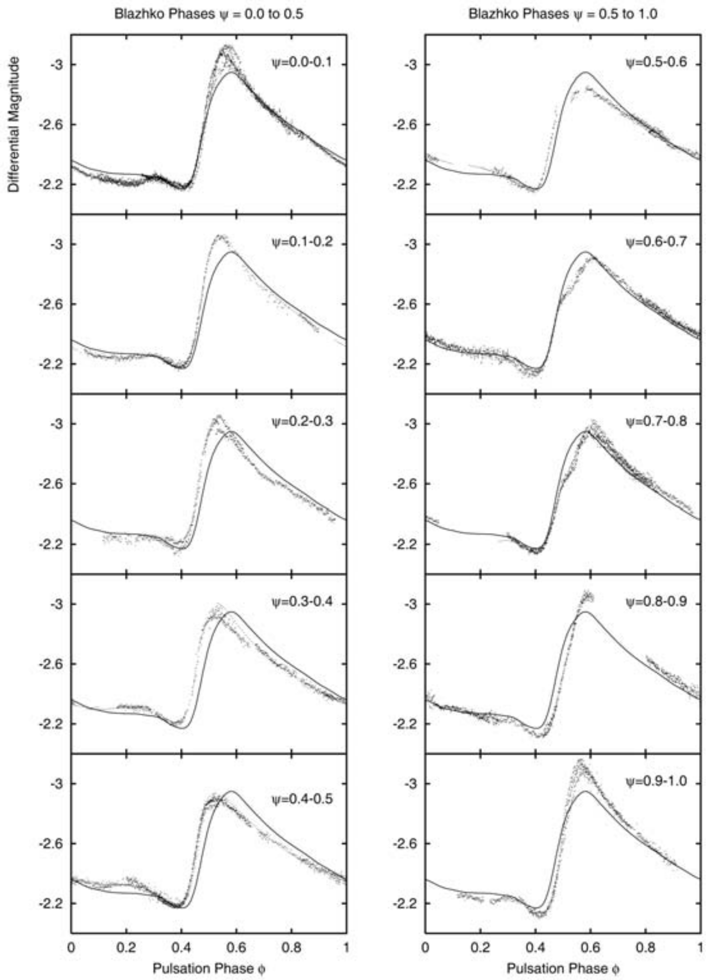

Figure 1. Light curve variations over the Blazhko cycle from photometric observations of RR Lyrae. The data were acquired by the Blazhko Project through a multi-site campaign in 2003-2004 from 6 different observatories in the northern hemisphere. The ten panels show the data for consecutive phase intervals in the Blazhko cycle of about 39 days (see Section 4). The full line represents the mean light curve derived from all data. It is clear that certain features in the light curve occur at specific phase intervals in the Blazhko cycle. Studying their origin and modelling those changes can bring us closer to understanding the modulation.

pulsation modes. I refer to Smith (1995) for an extensive and comprehensive review on RR Lyrae stars.

The Blazhko effect is not a rare phenomenon, it turns out. So far about 20-30% of the galactic RRab stars show the Blazhko effect (Szeidl 1988; Moskalik

& Poretti 2003; Kovács 2005). In the Large Magellanic Cloud this percentage is somewhat lower (12%, Alcock et al. 2003). Among the RRc stars, the phenomenon is less common (about 5%, Moskalik & Poretti 2003; Alcock et al. 2000), though due to the lower pulsation amplitudes it is also harder to detect.

The Blazhko effect is recognized through the presence of close secondary peaks in the pulsation spectra of the affected stars. Many other types of pulsating stars also show amplitude/phase modulation and close frequencies (e.g., in Delta Scuti stars, see Breger & Pamyathnykh 2006), and it may be that the underlying mechanism is similar as for RR Lyrae stars.

2. The Blazhko Puzzle

Despite numerous theoretical and observational studies, the origin of the Blazhko effect is still a matter of controversy. The currently most cited explanations involve either a resonance effect or a magnetic field. In fact, both types of models call for the presence of nonradial modes, whereas until recently RR Lyrae stars were considered to be purely radial pulsators.

In the resonance models the idea of an interference or a coupling between two purely radial modes (Borkowski 1982; Moskalik 1986) has long been abandoned. Van Hoolst et al. (1998), Nowakowski & Dziembowski (2001), and Dziembowski & Mizerski (2004) argue for nonradial mode excitation through a nonlinear resonant coupling as the cause of the Blazhko effect. Nonradial modes of harmonic degree $\ell = 1$ have the highest probability to be nonlinearly excited and give rise to amplitude and phase modulation.

The observation of even longer cycles, of the order of years, in some well observed Blazhko stars (about 4 years for RR Lyr, 7 years for RW Dra, 9 years for XZ Cyg, etc.) is reminiscent of the 11-year solar (magnetic) cycle. The magnetic models assume that Blazhko stars have a magnetic field inclined to the stellar rotation axis (Cousens 1983; Shibahashi & Takata 1995). The magnetic Lorentz force deforms the radial mode to have additional quadrupole ($\ell = 2$) components along the magnetic axis. As the star rotates, the amplitide modulation is caused by the changing view upon these components. Determining magnetic fields in RR Lyrae stars through Zeeman splitting is not an easy observational task, since these stars are quite faint. (RR Lyr, with a visual magnitude between 7.2 and 8.2 is by far the brightest.) Whereas Babcock (1958) and Romanov et al. (1994) reported a variable magnetic field in RR Lyr with a strength up to 1.5 kG, Preston (1967) and Chadid et al. (2004)contradict these measurements. The observed frequency spectra of Blazhko stars offer no evidence for the magnetic models. Hence, a new and conclusive determination of the magnetic field strength in RR Lyrae variables, both Blazhko and non-modulated stars, would be of extreme importance for solving the Blazhko puzzle.

3. The Blazhko Project

In their present form, neither of both models satisfactorily explains the variety of features diplayed by Blazhko stars. They need fine-tuning with observations. The frequency peaks close to the main frequency in the pulsation spectra are a direct observational evidence that nonradial modes may indeed be excited. The decisive observational confirmation that the modulation is indeed caused by non-radial mode excitation may come from analysis of high-resolution spectroscopic data. Such an analysis has already been undertaken by Kolenberg (2002), but more extensive data are needed for a firm conclusion.

In this framework, the Blazhko Project is an international collaboration bridging the gap between theory and observations of the Blazhko phenomenon (see also Kolenberg 2005). The project is centered in Vienna and started its activities at the end of 2003.

In addition to the large existing data sets of Blazhko stars, we carry out extensive observations of a sample of critically selected field Blazhko stars, as well as a few non-modulated stars. Photometric data gathered over several Blazhko cycles ensure the required frequency resolution. At the same time, spectroscopic data collected at critical time intervals over the Blazhko cycles of the targets can reveal decisive information on the pulsation modes occurring in these stars. The findings are directly confronted with the theoretical models.

More on the Blazhko Project, the ongoing campaigns and their outcome so far can be found on the dedicated website http://www.univie.ac.at/tops/blazhko/.

4. Multi-site Campaigns

In the framework of this conference paper, we report on the results of a multi-site photometric campaign devoted to the brightest Blazhko star, RR Lyr. The strength of such campaigns on RR Lyrae stars is that they can be carried out with small telescopes and relatively modest equipment, and nevertheless lead to important discoveries.

During the whole observational season of 2004, photometric data of RR Lyr were acquired from six observatories with small telescopes (0.13-m up to 0.8-m), including the Ankara University Observatory. In addition, seven telescopes (1.2-m up to 9-m) recorded spectroscopic data, evenly spread over the Blazhko cycle.

The multi-site photometric campaign allowed for a detailed study of the light curve variations over the Blazhko cycle (see Figure 1). In addition, we found that the Blazhko period, previously reported to be 40.8 days, has become significantly shorter, about 39 days (Kolenberg et al. 2006). A changing Blazhko period, as was also reported by LaCluyzé et al. (2004), challenges the models in which the modulation period is directly linked to the rotation rate of the star.

The light curve variations and specific features are now being confronted with hydrodnamical models developed by Feuchtinger (1999) and Dorfi & Feuchtinger (1999). Is it possible to fit the observed light curves at different phases in the Blazhko cycle by fine-tuning the parameters of these models? What can we glean from the success or failure of that effort? Where do the nonradial modes come into play in modelling the light curves? And the spectra?

We intend to follow up on RR Lyr and other targets in ongoing and future multi-site campaigns.

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References

Alcock, C., Allsman, R., Alves, D. R., et al. 2000, ApJ, 542, 257
Alcock, C., Alves, D. R., Becker, A., et al. 2003, ApJ, 589, 597
Blazhko, S. N. 1907, Astron. Nachr., 173, 325
Borkowski, K. J. 1980, Acta Astron., 30, 393
Chadid, M., Wade, G. A., Shorlin, S. L. S., & Landstreet, J. D. 2004, A&A, 413, 1087
Cousens, A. 1983, MNRAS, 203, 1171
Breger, M., & Pamyathnykh, A. A. 2006, MNRAS, 368, 571
Dorfi, E. A., & Feuchtinger, M. U. 1999, A&A, 348, 815
Dziembowski, W. A., & Mizerski, T. 2004, Acta Astron., 54, 363
Feuchtinger, M. U. 1999, A&A, 351, 103
Fringant, A.-M. 1961, Journal des Observateurs, 44, 165
Kolenberg, K. 2002, PhD Thesis, University of Leuven, Belgium, http://www.ster.kuleuven.ac.be/pub/kolenberg_phd/
Kolenberg, K. 2005, ASP Conf. Ser., 335, 95
Kolenberg, K., Smith, H. A., Gazeas, K. D., Elmaslı, A., Breger, M., Guggenberger, E., Van Cauteren, P., Lampens, P., Reegen, P., Niarchos, P. G., Albayrak, B., Selam, S. O., Özavcı, İ., & Aksu, O. 2006, A&A, 459, 577
Kovács, G. 2005, A&A, 438, 227
LaCluyzé, A., Smith, H. A., Gill, E.-M., et al. 2004, AJ, 430, 1049
Moskalik, P., & Poretti, E. 2003, A&A, 398, 213
Moskalik, P. 1986, Acta Astron., 36, 333
Nowakowski, R. M., & Dziembowski, W. A. 2001, Acta Astron., 51, 5
Preston, G. W. 1967, in: The Magnetic and Related Stars, (Baltimore: Mono Book Corp.), 3
Preston, G. W., Smak, J., & Paczynski, B. 1965, ApJS, 12, 99
Romanov, Yu. S., Udovichenko, S. N., & Frolov, M. S. 1994, Bul. Spec. Astrophys. Obs., 38, 169
Shapley, H., 1916, ApJ, 43, 217
Shibahashi, H., & Takata, M. 1995, ASP Conf. Ser., 83, 42
Smith, H. A. 1995, RR Lyrae Stars, Cambridge Astrophysics Series, No. 27, (Cambridge, UK: Cambridge University Press)
Smith, H. A., Church, J. A., Fournier, J., et al. 2003, PASP, 115, 43
Szeidl, B. 1976, in ASSL Vol. 60, Multiple Periodic Variable Stars, ed. W. S. Fitch, (Dordrecht: D. Reidel Publishers), 133
Szeidl, B. 1988, in Multimode Stellar Pulsations, ed. G. Kovacs, L. Szabados & B. Szeidl, (Budapest: Konkoly Observatory, Kultura), 45
Szeidl, B., & Kolláth, Z. 2000, ASP Conf. Ser., 203, 281
Van Hoolst, T., Dziembowski, W. A., Kawaler, S. D. 1998, MNRAS, 297, 536