Mem. S.A.It. Vol. 77, 498

Memorie della

How to make progress in the understanding of the Blazhko effect

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Abstract. Almost a century after its discovery the Blazhko effect in RR Lyrae stars remains a mystery. The Blazhko Project is an international collaboration focusing at a better understanding of the phenomenon. In this short paper we summarize some of the results obtained so far, and point out some of the remaining challenges.

Key words. Stars: RR Lyrae – Stars: oscillations – Techniques: photometric – Techniques: spectroscopic

1. Introduction

Amplitude and phase variations are a common feature in many types of pulsating stars in different stages of their evolution (see also Breger & Pamyatnykh, this proceedings). This phenomenon was first detected in the astrophysically important class of RR Lyrae stars, and was called Blazhko effect after one of its discoverers (Blazhko 1907). We refer to Smith's paper in this proceedings for a general introduction. Though RR Lyrae stars have for a long time been considered prototypes of purely radially pulsating stars, all attempts to model the Blazhko effect based on only radial mode interactions have failed. Throughout the past decade most speculations about the origin of the phenomenon have centered on two classes of models, both involving the presence of **nonradial oscillations**. Simply put, the resonance models (see, e.g., Nowakowsi & Dziembowski 2001) favor the excitation of nonradial dipole modes (degree $\ell = 1$), whereas in the magnetic models (see, e.g., Shibahashi 2000) the radial mode is deformed by the magnetic field to have additional quadrupole components (degree $\ell = 2$). In this way, the identification of the additional, supposedly nonradial, modes in modulated stars, will help us to better understand the origin of the Blazhko effect.

Hence, the possible key to the century-old problem lies in a combined photometric and spectroscopic study of the modulated stars. Photometric data over several Blazhko cycles ensure the required frequency resolution. On the other hand, spectroscopic data obtained at well-chosen times over the

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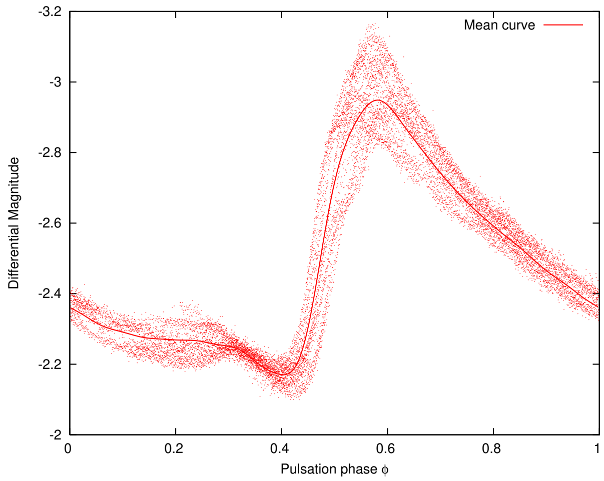

Fig. 1. The combined RR Lyr *V* band photometry gathered in 2003 and 2004 folded with the main pulsation period. The full line shows the mean light curve derived from all data.

Blazhko cycle offer the best diagnostic to reveal crucial information about the pulsation modes occurring in the stars. In this framework the Blazhko project was founded, a large international collaboration focused on the Blazhko effect (see also Kolenberg 2005). For details on the project and for the present status and outcome of the ongoing campaigns we refer to the dedicated website: http://www.astro.univie.ac.at/tops/blazhko/.

2. First results of the Blazhko project

2.1. RR Lyrae 2003-2004 campaign

So far, one of the main targets of the Blazhko Project has been RR Lyrae, the brightest and best studied RR Lyrae star. From the autumn of 2003 onwards, and during the whole observational season of 2004, six telescopes (0.13-m up to 0.8-m) obtained photometric data (see Figure 1) over more than 10 Blazhko cycles.

An important result following from the present photometric dataset on RR Lyrae is that the Blazhko period, previously known to be about 40.8 days, has become notably shorter: shorter than 39 days. This definitely confirms the observations made by Smith et al. (2003, and references therein) of a Blazhko period smaller than 40.8 days for RR Lyrae, and reminds one of the recent observations published by LaCluyzé et al. (2004) on the changing Blazhko period of XZ Cyg. Observations of **changing Blazhko periods** argue against any theoretical explanation that requires the Blazhko period to be directly proportional to the rotation period of the star. The crucial step towards the solution of the Blazhko problem is obtaining an unambiguous mode identification of the additional mode(s) occurring in modulated RR Lyrae stars. Earlier results (see Kolenberg 2005, and references therein) pointed towards the presence of an additional nonradial mode with low degree ($\ell = 1$ or $\ell = 2$). A more precise identification was hampered by the limited signal-to-noise ratio of the data and the incomplete sampling over the Blazhko cycle. The lack of accurate spectroscopic data on a Blazhko star was remedied by the 2004 spectroscopic campaign devoted to RR Lyr, in which seven telecopes (1.2-m up to 9-m) contributed to an impressive set of spectra, well-spread over the Blazhko cycle, gathered between March and November 2004. The two competing models for the Blazhko effect produce slightly different line profile

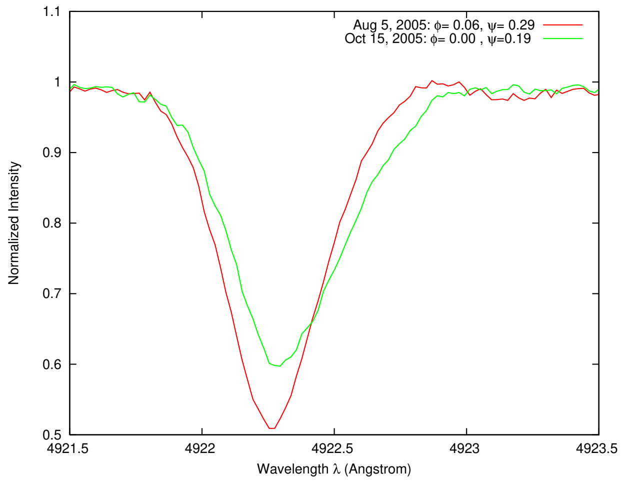

Fig. 2. The profile of the FeII line at 4923.921 Å , recorded with the spectrograph attached to the HET (9-m telescope) at McDonald observatory ($S/N = 200$). The spectra were gathered around the time of maximum light but at different Blazhko phases, allowing the study of spectral variations over the modulation cycle.

variations, which can only be discerned in very detailed spectroscopic data (see Figure 2). Spectral lines formed at different levels in the atmosphere reveal the Van Hoof effect (phase lag), well-known to occur in the turbulent atmospheres of RR Lyr stars. Modelling these line profiles requires taking into account the atmospheric changes in RR Lyrae over the pulsation and the Blazhko cycle, the nonlinear behaviour of the main radial mode, as well as additional nonradial components in the stellar pulsational velocity fields. Why do some stars show the Blazhko effect while other stars of similar observed properties do not? A possible answer to this question may be found in a detailed spectroscopic comparison of a Blazhko star with a non-modulated star. Therefore we will compare our RR Lyr data with newly gathered spectroscopic data over one pulsation cycle of SU Dra, a non-modulated RR Lyrae star of comparable metallicity. Similar studies will be carried out for other Blazhko stars.

2.2. Other ongoing campaigns

The Blazhko Project also focuses on new Blazhko candidates (see Kolenberg et al. 2005). A photometric campaign was devoted to TV Boo, the only known RRc Blazhko field candidate, and confirmed strong amplitude modulation in this star.

An extensive photometric campaign was carried out from the South African Astronomical Observatory, and Siding Springs Observatory (Australia) to fine-tune the knowledge on five southern field Blazhko targets which have not been extensively studied yet.

3. Simple questions, simple answers?

The frequency spectra of light curves of RR Lyrae Blazhko stars exhibit either a doublet or an equally-spaced triplet structure, with a very small frequency separation close to the main radial pulsation component, corresponding to the frequency of the modulation (Figure 3). If a triplet structure is observed, both side peaks appear to have unequal amplitudes, most often with the larger modulation peak at the higher frequency side of the main pulsation component, a still puzzling statistical fact. The continuous transition between the variables showing an equidistant triplet and those displaying

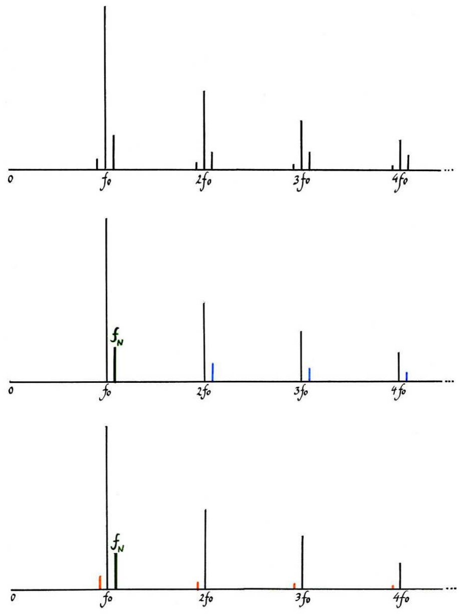

Fig. 3. The typical frequency spectrum of a Blazhko star (top) can be decomposed into sum and difference combinations (middle and bottom) of f_0, its harmonics and an additional mode f_N (right sidepeak) with a frequency close to f_0. A possible explanantion for the lower left sidepeaks is that they result from a combination with a higher order harmonic than the right sidepeaks.

only a close doublet suggests that both features are the result of the same phenomenon. A simple way of interpreting the spectrum of a Blazhko star starts from the assumption that in reality there are only two modes present in the star. On the one hand, there is the main radial mode, which in the case of a fundamental mode RRab pulsator has a large amplitude and behaves nonlinearly. Hence, we see the harmonics of this frequency up to a high order. On the other hand, we observe a frequency f_N, close to the main frequency, related to an additional mode, the mode we think is responsible for the amplitude and phase modulation. Let's assume here that only the right sidepeak frequency (the one usually higher) is related to a real mode. Because of its frequency value, this mode must be nonradial, and since it has a much smaller amplitude in both photometric and radial velocity data, it can be considered as behaving in a linear fashion, at least in the zone where most of the pulsation takes place.

By making sum and difference combinations of the main frequency f_0 and its harmonics kf_0 with the nonradial mode f_N all frequencies occurring in a typical Blazhko spectrum can be explained, as well as the equidistancy in the triplets (Figure 3). The right sidepeaks in the triplet structures around the harmonics result from the sum combinations, whereas all the left sidepeaks can be explained by differences. The generally lower (and sometimes barely visible) left sidepeaks may be explained as resulting from a combination with a higher harmonic. The simple picture may be disturbed by resonances in the star, which could enhance or diminish the actually observed amplitudes of the frequencies. This simple model raises a lot of complicated questions, e.g., concerning the nature of combination frequencies, but it is certainly worth exploring further.

Acknowledgements. Part of this investigation has been supported by the Austrian Fonds zur Förderung der wissenschaftlichen Forschung, project number P17097-N02. It is a pleasure to acknowledge the valuable help of all people involved in the Blazhko Project (see http://www.astro.univie.ac.at/tops/blazhko/) .

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