

# Behavior of the Doubling of Metal Lines as Function of the Blazhko Phase in the Spectra of RR Lyr

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In this work we analyse the doubling of metal lines as a function of the Blazhko phase in the spectra of RR Lyr.

## 1 Introduction

We present here the observation of the doubling line absorption in the spectra of the variable star RR Lyr using metal lines of FeII ( $\lambda 4923.921 \text{ \AA}$ ), and for the first time, the FeII ( $\lambda 4549.214 \text{ \AA}$ ) line. We observed high intensity of hydrogen emission lines  $H_\alpha$  and  $H_\beta$ , and two lines of HeI ( $\lambda 5875.66 \text{ \AA}$  and  $\lambda 6678.15 \text{ \AA}$ ) (Gillet et al., 2016; Sefyani et al., 2017). The observed He I absorption/emission lines are directly related to the intensity of the shock wave passing through the atmosphere of the star during the phase of maximum Blazhko cycle. During the photospheric expansion phase of the star and during the passage of the shock wave, we witnessed the disappearance of neutral FeI ( $\lambda 4934.006 \text{ \AA}$  and  $\lambda 4920.503 \text{ \AA}$ ) absorption lines and their reappearance at pulsation phase 1.00.

## 2 Observations and Data Reduction

Spectroscopic observing campaigns of RR Lyr were performed on 12 October 2013 and 28 – 29 – 30 October 2015 as well as during the night of 6 November 2015. The spectra were acquired using the *C14* telescope at Oukaïmeden observatory (Minor Planet Center code *J43*). The echelle spectrograph used has a resolution of 12000 with a dispersion of  $16 \text{ \AA/mm}$ . The wavelength calibration was performed with a thorium-argon lamp. The camera was cooled to  $-20^\circ\text{C}$  and maintained at this temperature during our observations. The exposure time was 300 s for each spectra. The spectra were filtered with a Gaussian filter at  $\sigma = 0.6$  pixels to minimise noise and increase sampling. The spectral dispersion was about  $0.11 \text{ \AA/pixel}$ . The measured

signal-to-noise ratio was about 30. The time resolution was:  $\Delta t/P \approx 0.006$  (0.6%). The spectrograph was equipped with a grating for dispersing light between 4100Å and 7200Å, between orders 32 and 52. The radial velocity presented are taken with respect to the barycenter of the star established in the heliocentric reference frame.

### 3 Metallic Line Doubling and Conclusion

It is well established that shock waves pass through the line forming regions of the star's atmosphere during each pulsation cycle. The measurements carried out by Chadid & Gillet (1996a) confirm, for the first time, the presence of doubling of metal lines in RR Lyr. They also observed the doubling in the form of broadening of the FeII ( $\lambda 4923.921 \text{ \AA}$ ) and of the MgI ( $\lambda 5183.604 \text{ \AA}$ ) lines. The physical interpretation of metallic line doubling was presented by Fokin & Gillet (1997). The strength of the doubling depends on the Blazhko phase according to the study made by Chadid & Gillet (1997). This suggests that the doubling of FeII is synonymous with the presence of a very strong shock wave observable at the maximum of the Blazhko cycle. We have observed for the first time (see Figure 1) the new doubling of the FeII line ( $\lambda 4549.214 \text{ \AA}$ ) occurring at phase 0.903 and the doubling of the FeII line ( $\lambda 4923.921 \text{ \AA}$ ) at phase 0.941 during the night of 12 October 2013, corresponding to the Blazhko phase 0.13. On the other hand, we did not observe any doubling of metal lines in the spectra corresponding to phases 0.26 and 0.47 of the Blazhko cycle, only line broadening occurred at this phase. The shock wave is strong enough to ionize the majority of iron atoms involved in the process of line doubling. During the passage of the shock wave, the FeI absorption lines ( $\lambda 4934.006 \text{ \AA}$  and  $\lambda 4920.503 \text{ \AA}$ ) disappeared while the FeII absorption line ( $\lambda 4923.921 \text{ \AA}$  and  $\lambda 4549.214 \text{ \AA}$ ) strengthened at pulsation phase of 1.00 in all Blazhko phases. From phase 1.00, the FeI line reappears at ( $\lambda 4934.006 \text{ \AA}$  and  $\lambda 4920.503 \text{ \AA}$ ).

### References

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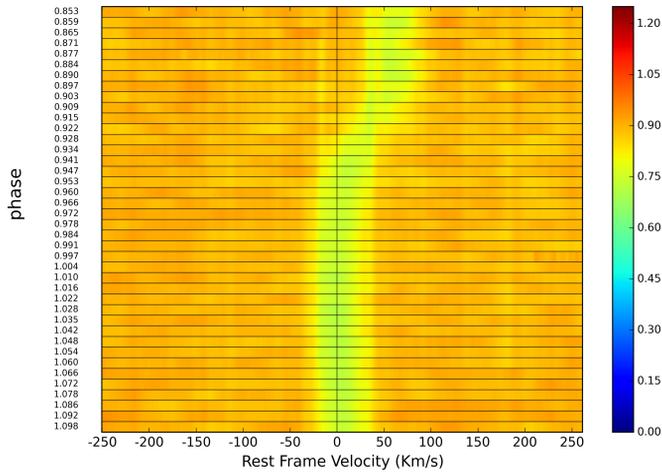


Fig. 1: Time series of FeII ( $\lambda 4549.214 \text{ \AA}$ ) line of RR Lyr, (increasing phase from top to bottom). Spectra are interpolated to provide a two dimensional map profile in the velocity range  $[-250, 250] \text{ km s}^{-1}$ . Velocities are given in the stellar rest frame with positive velocities corresponding to inward motion (toward the photosphere). The pulsation phase is given on the left side. On the right side, the color bar representing the flux is from 0.0 to 1.2.