RR Lyr Spectrophotometric Campaign from Oukaimeden Observatory

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In this work we present spectrophotometric results of the variable star RR Lyr, obtained during observational campaigns between 2015 and 2016 at the Oukaïmeden observatory in Morocco.

1 Introduction

RR Lyrae stars play a major astrophysical role as standard candles for distance determination and as witnesses of the evolution of the universe at a young age. These variables occupy a special place in the family of pulsating variable stars. They have been known for more than a century because of their large amplitude and pulsation period and were considered to be prototypes of pure radial pulsators, with periods ranging from a few hours up to a whole day. Their amplitude and phase modulations are well known as the Blazhko effect. Although these stars have been well studied, major questions concerning RR Lyrae stars still remain, in particular the origin of the so-called Blazhko effect (Gillet, 2013; Chadid & Preston, 2013; Gillet et al., 2013, Kollath, these proceedings). Through spectrophotometry, we aim to provide new insights into stellar pulsations, especially the atmospheric dynamics of high amplitude pulsators such as RR Lyr, in order to establish new models of the mechanical and thermal behavior of their atmospheres (shock waves, relaxation time, and energy loss).

2 Observing Campaigns and Instrumentation

The location of modern observatories requires high sky quality: good weather, isolated site to avoid any light pollution, high altitude for a better transparency, and to reduce temperature gradients (the main source of atmospheric turbulence). With an altitude of 2750 m, the region of Oukaïmeden in Morocco (longitude: $7^\circ\,52'\,52''$ West, latitude: $31^\circ\,12'\,32''$ North) meets most of these criteria. The campaigns took place at the Oukaïmeden Observatory, in the High Atlas Mountains, at an altitude

of 2700 m. The instrument setup includes two separate telescope tubes on the same mount. For spectroscopy, a $C14$ was used along with an echelle spectrograph (Chadid & Gillet, 1996) (125 mm $F/5$ collimator, $R2$ echelle Grating, cross-dispersing prism, 85 mm $F/1.8$ objective) from the Shelyak Company. For photometry, we use an ASA $10''$ and a QSI CCD camera including a filterwheel equipped with the Johnson UBV filters. This instrumentation setup is unique in the sense that both spectroscopy and photometry were carried out simultaneously.

3 Observations and Data Reduction

We conducted an observational campaign of RR Lyr during the summer of 2015. More than 1200 spectra were treated and analyzed. During 2016, we conducted an intensive observing campaign of RR Lyr that spanned over 7 months, and obtained spectroscopic data (34 nights) and photometric data (30 nights). The spectroscopic data covers a large part of the visible domain (4100 to 7200 Å), between orders 32 and 52, with an exposure time of 300 s seconds and a resolution of 12000.

4 Results: Evolution of the He Line Profile of RR Lyr

We noticed, for the first time, that the emission of the Fraunhofer D3 line (λ 5875.66 Å) of helium is visible on various Blazhko phases, including during the minimum of the Blazhko cycle. The emission of helium is usually observed during the expansion of the star's atmosphere. As indicated in Figure 1 by the vertical line, our observations show that this emission is present along the whole Blazhko cycle. Independently of the Blazhko cycle, the emission of the D3 line is visible at two specific pulsation phases; the first appearance of this emission occurs at pulsation phase 0.91 and a second appearance at pulsation phase 1.00 (to appear in a future article). This phenomenon thus takes place independently of the intensity of the shock wave crossing the atmosphere of the star during these phases of pulsation. We interpreted the second appearance (at pulsation phase 1.00) of the helium D3 line emission as a P-Cygni profile (Gillet & Fokin, 2014; Gillet et al., 2016). We note that the intensity of the second appearance of the emission of the D3 helium line is weaker than that of the first appearance, independently of the signal-to-noise ratio.

5 Conclusion

The presence of the P Cygni profile seems to be a natural consequence of the large extension of the expanding atmosphere which is induced by strong (radiative) shock waves propagating towards the high atmosphere (Gillet et al., 2016). We noticed, for the first time, that the emission of the D3 helium line during the expansion phase is visible during various Blazhko phases including during the minimum of the Blazhko cycle. Hence, D3 helium line emission is independent of Blazhko phase.

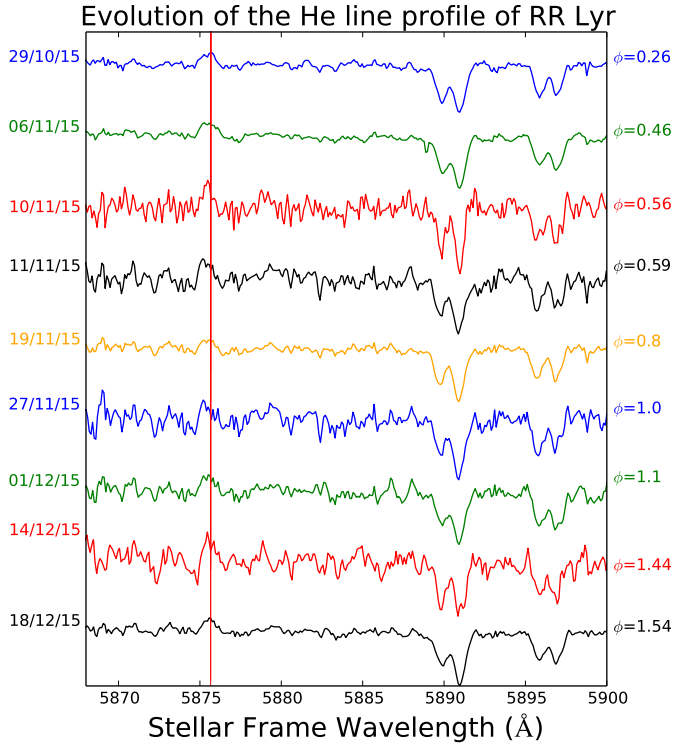

Fig. 1: Evolution of the He I (λ 5875.66 Å) line profile of RR Lyr at different Blazhko phases obtained by co-adding several spectra. The vertical line in this figure shows the first emission of the D3 line. The Blazhko phases (ϕ) are indicated on the right side. The date of the day of obtaining each spectrum is indicated on the left of the y-axis

References

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