**H\(\alpha\) and Gaia–RVS domain spectroscopy of Be stars and interacting binaries with Ondřejov 2m telescope**

P Koubský, L Kotková and V Votruba
Astronomical Institute, Academy of Sciences of CR, 251 65 Ondřejov, Czech Republic
E-mail: koubsky@sunstel.asu.cas.cz

**Abstract.** A long term project to investigate the spectral appearance over the Gaia–RVS domain of a large sample of Be stars and interacting binaries has been undertaken. The aim of the Ondřejov project is to create sufficient amounts of training data in the R VS domain to complement the Bp/Rp classification of Be stars which may be observed with Gaia. The project current status is described and sample spectra in both H\(\alpha\) and RVS domains are presented and discussed.

1. Introduction
Be stars are usually defined as early type stars with luminosity class III-V which once showed emission in at least one Balmer line. Emission components are usually not limited to Balmer series only, they may be present in Paschen, Brackett, Pfund, and Humphreys series too, and in lines of other ions like Fe II, Ca II or He I. The emission is attributed to a circumstellar envelope/disk. Despite the large effort in both observational and theoretical fields, its formation is not yet well explained. Emission can disappear and possibly re-appear again, with non-regular periods of several years. Moreover, Be stars are variable on other time-scales from hours to months, but the variations on the long-term scale (usually related to the building and decline of the disk) are the most important ones. In the case of interacting binaries, which mimic some properties of Be stars, variations are connected to the orbital period. The Be stars are not rare objects: they represent 17 % of all B stars (Zorec and Briot [1]).

Gaia onboard instruments ASTRO, Bp/Rp photometer, and RVS spectrometer should provide fundamental information about the yet unexplained Be phenomenon. Lobel et al. [2] processed the ground based spectra of emission line stars with the Gaia Object Generator to analyze simulated Bp/Rp photometer fluxes for objects up to G=15. They showed that Be stars can be located in the H\(\alpha\)/H\(\beta\) index diagram. In this paper we want to exploit the capability of the RVS data for a more precise description of the behaviour of Be stars observed by Gaia. In addition, infrared calcium triplet emission in Be stars is discussed.

The Gaia RVS – Radial Velocity Spectrometer – will cover Paschen, Ca II, and N I lines, which in case of Be stars can display complicated blends of both absorption and emission components (Munari and Tomasella [3]). Description of near IR spectra of Be stars can be found in the literature: An atlas of O-G0 stars in the infrared spectral region by Andrillat et al. [4], a very brief description of Paschen and Ca II IR lines in Jaschek et al. [5], or in Tomasella et al. [6].
Many Be IR spectra are available from digital archive: e.g. low resolution IR spectra (1000) of Be stars in the RVS domain in the MAST HPOL archive, high-resolution spectra of Be stars up to 8881 Å are available from the ESO FEROS archive, or from VLT UVES archive (gap 8540 – 8660 Å). No systematic attempt has been undertaken so far to investigate spectra of Be stars in the RVS domain of Gaia. Therefore, we decided to carry out a large scale documentation project on Be stars with the coudé spectrograph of the Ondřejov 2 m telescope. We want to compare Hα and Paschen spectra of Be stars and exploit the possibility to derive the properties and behaviour of the disk from the observations of higher member of the Paschen series. In addition, Ca II lines emission in Be stars and interacting binaries can be studied.

It is expected that the RVS spectrometer on board Gaia satellite will observe Be stars brighter than V=10 mag in the range 8470-8740 Å with a resolution of 10500 (6000 for fainter objects). In Figure 1 we give an example of Be spectrum taken in the framework of the Ondřejov project in the RVS Gaia domain. Signal to noise ratio is about 30 which should be available from Gaia data for stars of about V=13 (full mission). The spectral resolution is comparable with the synthetic RVS spectra (see Katz [7] for details).

2. Data collection and reduction
The spectra were obtained with Ondřejov single order spectrograph + SITe 2000x800 chip in the focus of a 702-mm camera (R=12000, 6250-6750 and 8392-8900 Å). In all cases, calibration arc frames were secured before and after each stellar frame. During each night, a series of flat field and bias exposures were obtained. The stellar and calibration spectra (Th-Ar and tungsten lamps) were reduced using IRAF. Spectra of about 150 Be stars both in Hα and Paschen region were collected.

Figure 1. Spectrum of Be star SAO 349 taken with the Ondřejov coudé spectrograph.
3. Results

3.1. Be stars

A straightforward relation between the properties of H\(_\alpha\) and Paschen profiles in Be stars is summarized in Figure 2. Spectra are ordered according to the normalized flux of H\(_\alpha\) emission in the approximate range from 13 to 3. Note that the H\(_\alpha\) profiles are without important central absorption component, i.e. the disks are seen under low inclination Silaj et al. [3]. In all cases the Paschen lines are in emission too. Thus, for Be stars with strong H\(_\alpha\) emission the Gaia RVS spectrometer, which will cover Paschen P16 – P13 profiles can provide independent information on H\(_\alpha\).

In Figure 3, Be stars with more complicated H\(_\alpha\) profiles are presented. They include narrow profiles like FW CMa, or combination of emission and absorption components like \(\phi\) And and cover smaller range of the normalized flux (6.3 – 1.1). One can see that all H\(_\alpha\) profiles stronger than 2.5 of normalized flux imply emission in Paschen lines. The presence of H\(_\alpha\) emission in \(\phi\) Aqr or V1507 Cyg (see subsection 3.2.) might be deduced from IR spectra after a careful analysis of Paschen profiles.

Figure 2. Spectra of Be stars in H\(_\alpha\) and Gaia RVS regions ordered according to the normalized flux of H\(_\alpha\) emission (numbers in the left corner of the middle panel, normalized fluxes for P16 are given in the right corner above the label for a particular star). All spectra are displayed both in a classical(normalized) way and in the gray scale representation. Spectra of Be stars with strong H\(_\alpha\) emission are shown.
Figure 3. As in Figure 2, but for Be stars with moderate Hα emission.

Figure 4. As in Figure 2, but for Be stars showing emission in Paschen and calcium lines.

3.2. Infrared calcium triplet emission
An interesting feature in the Gaia RVS region are the calcium triplet lines (λλ 8498, 8542, and 8662 Å) which "coincide" with Paschen lines P16, P15, and P13. In many Be stars both
Figure 5. As in Figure 2, but for Be stars with dominating Ca II emission.

the Paschen lines and calcium triplet lines show emission. In these cases the emission in P14 (not blended with Ca II) is fainter than in P15 and P13. However, some peculiar objects like v Sgr (hydrogen deficient binary), Mira Ceti stars, T Tau (pre-main sequence star) show solely calcium emission (no sign of emission in P14). The spectra of Be stars with Ca II infrared emission are displayed in Figures 4 and 5. Comparing Figures 2, 3 with Figure 4 we can deduce that the calcium emission enhances Paschen emission very often if not in all cases when the Hα disk is adequately strong. In Figure 5, examples Be spectra where the calcium triplet emission dominates are assembled. Some of them are proved interacting binaries (AX Mon, KK And, BR CMi), HD 81357 has been recently detected as a 33-d binary and its spectrum mimics BR CMi. The spectrum of V1507 Cyg, which is displayed in Figure 3, may belong also to this group. This 28-d binary system of very complex nature (Hutchings and Redman [9]) consists of a visible component which is loosing mass towards the more massive but observationally undetectable star due to its huge circumstellar envelope. On the other hand, there is no evidence of Roche-lobe filling secondary in BU Tau, and binarity of XX Oph, HR 894 or V4409 Sgr has not been confirmed. That leaves the suggestion by Polidan [10] that a possible connection between the presence of calcium triplet emission and binary nature of Be stars exists, still open. To our best knowledge, the Polidan’s idea has not been studied in more detail so far and we hope that the data from the Gaia RVS instrument could shed more light on this problem too.

4. Conclusions
We have shown that the data from Gaia Radial Velocity Spectrometer can be combined with Bp/Rp data for detecting Be stars with normalized flux of Hα emission larger than 2.5. The high incidence of interacting binary stars among those stars displaying calcium triplet emission is worthy of further study. We hope that the data from Gaia RVS would supply new interesting data for reliable modeling the circumstellar disks both in single stars and binaries.
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