Active OB stars: structure, evolution, mass loss, and critical limits
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Probing Be star disks: new insights from Hα spectroscopy and detailed numerical models

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Abstract. Hα high resolution spectroscopy combined with detailed numerical models is used to probe the physical conditions, such as density, temperature, and velocity of Be star disks. Models have been constructed for Be stars over a range in spectral types and inclination angles. We find that a variety of line shapes can be obtained by keeping the inclination fixed and changing density alone. This is due to the fact that our models account for disk temperature distributions self-consistently from the requirement of radiative equilibrium. A new analytical tool, called the variability ratio, was developed to identify emission-line stars at particular stages of variability. It is used in this work to quantify changes in the Hα equivalent widths for our observed spectra.

Keywords. stars: emission-line, Be, line: profiles, radiative transfer, circumstellar matter, stars: activity

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1. Introduction

B-emission or Be stars are characterized by Balmer emission lines in their spectra due to the presence of a disk-like distribution of circumstellar gas. Often the Hα Balmer line is the most prominent feature. Consequently, the study of the Hα spectral line, including its shape, equivalent width (EW), and variability, offers a valuable probe of Be star disks.

Here we present the main results from a thorough study of Hα line profiles for Be stars built from models with a wide range of input parameters, on the basis of non-LTE calculations of Be disk systems. Our models were compared to 69 Be star/disk systems (Silaj *et al.* 2010). We also investigate the variability of many of these systems by monitoring the change in Hα EW calculated from observed spectra acquired over a period of about 4 years. We found a simple method to quantify the changes in the spectra, called the variability ratio. This technique requires relatively little observational data, and can be used to find these stars in particular stages of variability. Alternatively, it can be used to determine when a star/disk system is changing and needs to be monitored closely.

2. Results

A common misconception in the literature is that the shape of certain spectral lines can be used to infer the inclination angle of a disk system. We showed that this was generally not true in all cases and that computing a self-consistent disk thermal structure is critical to interpreting observations. Fig. 1 shows B0 Hα line profiles (far left) and their corresponding temperature structures (right) for four different models with inclinations of 20^o and 45^o. (The power law index, n, and the assumed base density at the stellar surface, ρ_o, are parameters related to the density distribution (see Sigut & Jones (2007)

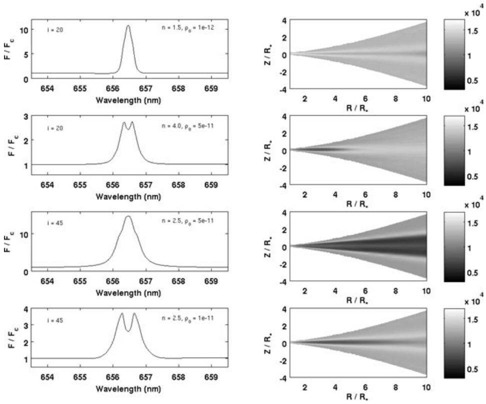

Figure 1. Model B0 Hα line profiles (left) and their corresponding temperature structures (right) for four different models with inclinations of 20^o and 45^o. KEY: Line profile shapes can vary due to changes in disk density alone when the temperature is accounted for self-consistently (Silaj *et al.* 2010).

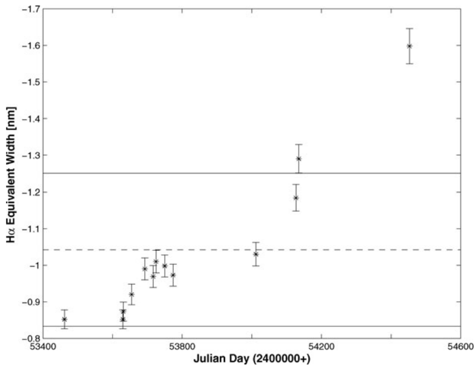

Figure 2. A plot showing the change in Hα equivalent width as a function of time for the star BK Cam (HR 985). The estimated error for each observation is shown by the errors bars. The middle dashed horizontal line corresponds to the mean of the EW. The upper and lower solid horizontal lines correspond to $\overline{EW}$ $\pm$ one standard deviation (Jones *et al.* 2011).

for greater detail). Notice that for a given inclination the line shifts from singly peaked to doubly peaked with a change in disk density alone.

A necessary prerequisite to the development of successful dynamical models will be timely observations that adequately sample the disk loss and disk growth events for Be stars. Many Be stars are known to be variable and the study of this variability has had a long history. The variability occurs over a wide range of time scales from periods much less than a day to periods as long as decades. A successful model must account for this observed variability. Therefore, it is crucial to monitor the system at particular stages of variability, for example, during a disk loss or growth event, if we hope to improve our understanding of these systems. We have developed a new tool that offers a simple but powerful method to place bounds on the degree of variability of particular systems based on statistical analysis of changes in Hα EW over time.

Fig. 2 shows an example of the change in Hα EW for the star, BK Cam (HR 985) during our investigation. We calculate a variability ratio, R from the ratio of standard deviation to the mean uncertainty. Based on our preliminary work, we calculate $R = 6.6$ which falls into our variable category. We are currently refining our statistics for our program stars.

3. Future Work

We are currently completing a thorough study of Hα profiles for Be shell stars. As a continuation of our work on the variability of Be stars, we are using our detailed models, in steps, to simulate dynamic models.

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