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Spectrally and spatially resolved Hα emission from Be stars: their disks rotate Keplerian

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Abstract. We test whether Be star disks rotate in a Keplerian or an Angular Momentum Conserving fashion. This is done by employing sub-milli arcsecond spectroastrometry around Hα. We spatially resolve the disks, and are the first to do so at such a high spectral resolution. We fit the emission line profiles with parametric models. The Keplerian models reproduce the spectro-astrometry, whereas the AMC models do not, thereby supporting the viscous disk model for Be stars.

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Knowing the kinematics of Be star disks will inform us about the formation of these disks. We aim to directly determine the kinematics of Be disks: Keplerian as expected for viscous excretion disks or angular momentum conserving, requiring different models? Such a study has only been done previously using barely spectrally resolved interferometric data (Meilland *et al.* 2007). We embarked on a high angular resolution survey of half a dozen objects, and present here our results on β CMi

We approach the problem using spectro-astrometry. This technique allows the detection of extended structures at sub-milli-arcsecond (mas) precision in longslit spectra (see also e.g. Wheelwright *et al.* 2010; Oudmaijer et al. 2008). As an example, the left graph in Fig.1 shows several velocity slices of a rotating disk. The disk is only a few mas large, and note that the higher the velocity, the smaller the disk. The right-hand

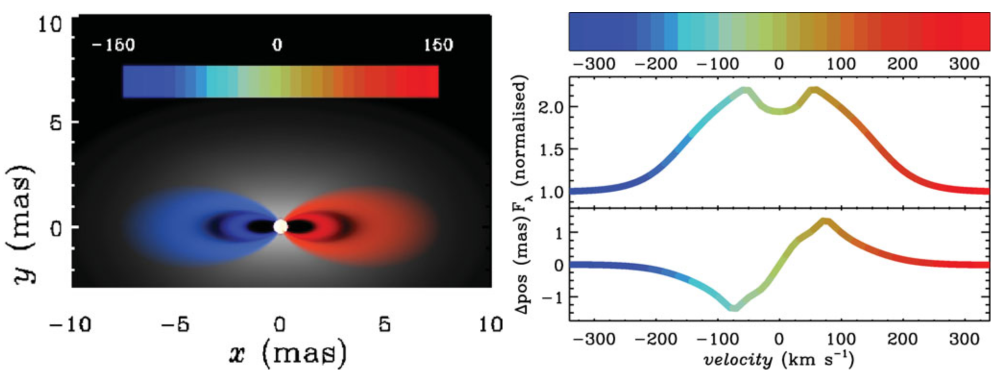

Figure 1. The left-hand image shows the spatially extended emission from a rotating disk for different velocities. Right: The top panel shows the resulting Hα emission line profile, and the bottom panel the expected excursion in the spectro-astrometry.

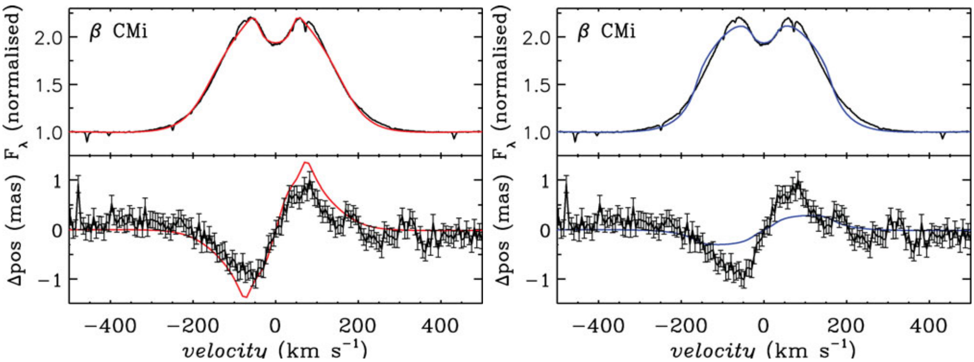

Figure 2. The top panels show the Hα line profile of β CMi, and the bottom panels its spectro-astrometric signature. Overplotted are a Keplerian fit (left) and an AMC fit (right) to the emission line. The Keplerian model reproduces the spectro-astrometry very well. The AMC model not at all.

panel shows how the total intensity spectrum of the line would look like. Normally this emission is not spatially resolved due to the small disks. However, if we take a longslit spectrum in the optical we can measure the position of the peak emission (essentially the photo-centre) as function of velocity with sub-milli-arcsecond precision, even in arcsecond seeing. The bottom panel of the right-hand figure shows how such a disk looks like in spectro-astrometry. The blue-shifted emission is located on one side of the star and the red-shifted emission on the other side, as expected. The spectro-astrometry measures the position of the photo-centre of the line emission and this shifts up to 1 mas.

We show our UVES/VLT data of β CMi (B8Ve) in Fig. 2. The rotating disk is clearly detected in the spectro-astrometry (bottom-panel), and indeed, has the same shape as expected from Fig. 1. This is the first time that this line is spatially resolved at such a high spectral resolution ($\sim$4 km/s). We interpret the data with a model to determine the disk's kinematical structure.

We fit the spectrum and predict the astrometry using both a Keplerian rotating and angular momentum conserving (AMC) disk using the prescription of Grundstrom & Gies (2006). Both models can fit the Hα emission line profile without any problems. However, while the Keplerian disk (left) also comfortably reproduces the spatial profile, the AMC does not at all (right). This is because of its steeper drop in rotation speed, the AMC disk is typically 10 times smaller (with a photo-centre several times smaller) than the Keplerian disk when matching the observed rotation velocities.

To summarize, both models easily fit the emission line profiles, but the additional constraint of spatially resolved data allows us to distinguish between the two. We conclude that the disks around Be stars rotate in a Keplerian fashion, and are not Angular Momentum Conserving. We have data of more Be stars in hand and are fitting the data simultaneously with the infrared excess and polarization using the HDUST model by Carciofi & Bjorkman (2006).

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