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# Multi-epoch interferometric observations of the Be star ζ Tau

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**Abstract.** We present interferometric observations of the Be star $\zeta$ Tau obtained using the MIRC beam combiner at the CHARA Array during four epochs in 2007–2009. Fitting a geometric model to the data reveals a nearly edge-on disk with a FWHM of $\sim 1.8$ milli-arcsec in the $H$-band. The non-zero closure phases indicate an asymmetry in the brightness distribution. Interestingly, when combining our results with previously published interferometric observations of $\zeta$ Tau, we find a correlation between the position angle of the disk and the spectroscopic $V/R$ ratio, suggesting that the tilt of the disk might be precessing. This work is part of a multi-year monitoring campaign to investigate the development and outward motion of asymmetric structures in the disks of Be stars.

**Keywords.** techniques: interferometric, circumstellar matter, stars: emission-line, Be

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The bright Be star $\zeta$ Tau is an ideal target for optical/infrared interferometry. We used the MIRC beam combiner at the CHARA Array to measure interferometrically the size and orientation of the disk of $\zeta$ Tau in the $H$-band over four epochs in 2007–2009. The visibilities provide information on the size, orientation, and inclination of the disk. The non-zero closure phases indicate an asymmetry in the brightness distribution.

We fit a two component geometric model to the MIRC data obtained for $\zeta$ Tau. The model is composed of a uniform disk with an angular diameter 0.40 mas ($R = 5.5\ \mathrm{R}_\odot$) to fit the central star and an elliptical Gaussian surface brightness distribution to model the circumstellar disk. To account for the asymmetry, we modulated the elliptical Gaussian disk by a sinusoid as a function of azimuth. This creates a skewed disk model where the sinusoid causes the brightness distribution to peak on one side of the disk and places a depression in the brightness on the other side. The models are shown in Figure 1.

Over the four epochs, the FWHM of the major axis of the disk ranges between 1.6 – 2.1 mas in the $H$-band. This is similar to the $K'$-band size of 1.8 mas computed by Gies *et al.* (2007) and smaller than the 3.1 – 4.5 mas FWHM measured in H$\alpha$ by Quirrenbach *et al.* (1997) and Tycner *et al.* (2004). We find that the star contributes on average about 55% of the light in the $H$-band. In comparison, the star contributes 41% of the flux in the $K'$-band (Gies *et al.* 2007). These ratios are consistent with near-IR excess fluxes observed by Touhami *et al.* (2010).

Combining our results with previous interferometric observations, we find that the position angle of the major axis of the $\zeta$ Tau disk varies as a function of the spectroscopic $V/R$ phase (see Fig. 2). The disks of Be stars may develop a global, one-armed spiral instability. The oscillation mode forms a spiral density enhancement that precesses prograde with the disk rotation with a cycle time of a few years. We suspect that the

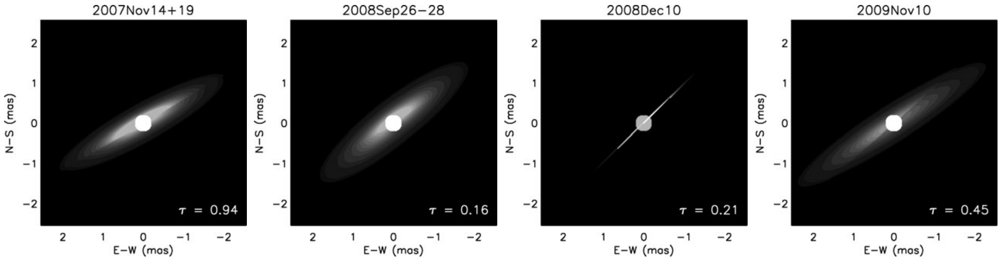


**Figure 1.** Best-fit geometric models for $\zeta$ Tau during the epochs of the MIRC observations. The spectroscopic $V/R$ phase $\tau$ is indicated in the bottom right of each panel.

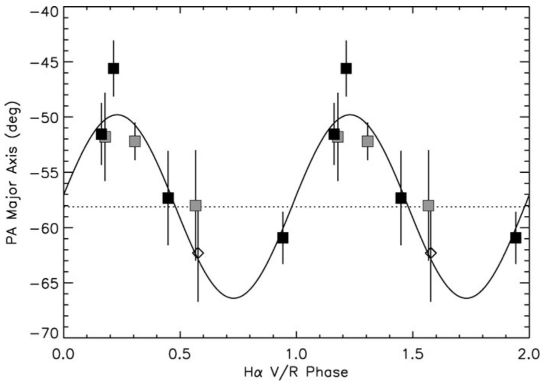


**Figure 2.** Position angle of the disk major axis for $\zeta$ Tau derived from interferometry plotted against the $V/R$ phase. The measurements are repeated over two cycles to emphasize phase continuity. The filled black squares represent our MIRC observations, the gray squares are previously published near-IR measurements (Gies *et al.* 2007, Štefl *et al.* 2009, Carciofi *et al.* 2009), and the open diamond indicates the H$\alpha$ result from Tycner *et al.* (2004). The solid line shows a sinusoidal weighted fit of the variation (mean PA -58.0°±1.4°, semiamplitude 8.1°±1.7°). The dotted line indicates the mean position angle of -58.1°±1.2° determined from linear polarization observations (McDavid 1999, Štefl *et al.* 2009).

position angle variations result from a tilt of the disk that could be generated by vertical motions of the gas caused by the spiral density enhancement (Ogilvie 2008; Oktariani & Okazaki 2009) as it moves through the disk. Additionally, we find that the asymmetry in the light distribution of the disk roughly corresponds to the expected location of the density enhancement in the spiral oscillation model.

We plan to continue monitoring changes in the structure and orientation of the disk of $\zeta$ Tau with future observations at the CHARA Array.

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