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Multi-wavelength Study of the Be/X-ray Binaries

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Abstract. An anti-correlation between the optical brightness and the strength of the Hα emission was observed from two Be/X-ray binaries, A0535+26 and MXB 0656-072: when the optical brightness showed a decrease, the intensity of the Hα emission displayed an obvious increase. This anti-correlation is interpreted as the result of the mass ejection from the Be star. After the mass ejection event, a cavity or low-density region will be developing in the inner parter of the circumstellar disk. The X-ray outbursts of the Be/X-ray binaries might be connected with the mass ejections from the Be star.

Keywords. Stars: neutron, stars: emission line, X-rays: binaries.

1. Introduction

Be/X-ray binary represents a major subclass of high mass X-ray binary in our Galaxy (Liu *et al.* (2006)). A neutron star moves in a wide and eccentric orbit around the Be star, which is a non-supergiant rapid-rotating B-type star and ever shows Balmer emission lines at least once in its life (Porter & Rivinius (2003)). There are two different disks in Be/X-ray binary: a circumstellar disk around Be star and an accretion disk around neutron star (see Reig (2011)) and the reference therein).

The optical thick Hα emission line in Be star is generally believed to be formed in the entire circumstellar disk (Slettebak *et al.* (1992)), while only the innermost part of the disk contributes significantly to the continuum flux. Due to the higher ionization potential energy, the formation region of the HeI λ6678 line should be smaller than the nearby continuum region (Stee *et al.* (1998)). The increase of the Hα intensity indicates that an extended circumstellar disk is forming around Be star, while the decrease of the V-band brightness suggests that a low-density or cavitated region is developing in the inner part of the disk.

2. The Anti-correlation between the Hα Intensity and the V-band Brightness

We carried out the optical spectroscopic observations on two Be/X-ray binaries, A0535+26 and MXB 0656-072, with the 2.16m telescope at Xinglong Station, NAOC. The anti-correlation between the Hα emission and the V-band brightness, a low V-band emission level with a strong Hα emission, was observed from both Be/X-ray binaries.

We observed a strong Hα emission, with an EW of -25 Å, in the Be/X-ray binaries A0535+26, during our 2009 observations, which was carried out just before the 2009 strong X-ray outburst of the system. In the same time, the V-band brightness of the system showed an obvious decrease (see Fig. 4 in Yan *et al.* (2012a)). The increase of

the Hα emission might be caused by the decrease of the continuum emission. In fact, the Hα emission of A0535+26 was in a low level while the V-band brightness was still in a decline phase during our 2010 observations (see Fig. 4 in Yan *et al.* (2012a)). Therefore, we suggest the anti-correlation between the Hα emission and the V-band brightness during our 2009 observations should be caused by the physical changes in the circumstellar disk around Be star. The same phenomenon was also observed in the Be/X-ray binary, MXB 0656-072, during our 2007 observations, which was taken just before a Type I X-ray outburst of the system (see Fig. 8 in Yan *et al.* (2012b)).

3. Mass ejections from the Be Star

The similar observational results were also observed in other Be/X-ray binaries, such as 4U 1145-619 (Stevens *et al.* (1997)) and 4U 0115+63 (Reig *et al.* (2007)). It should be a common feature in the Be/X-ray binaries. Observational results (Rivinius *et al.* (2001)) and theoretical calculations (Meilland *et al.* (2006)) suggest that a low-density region seems to develop around the Be star after an outburst. It was suggested that the outburst might be connected with the increased mass loss or mass ejection from the Be star. Some weeks to months after the outburst, the stellar radiation pressure could gradually excavates the inner part of the disk and a low-density region would develop around the Be star and slowly grow outward. With the vacuation of the inner disk, the optical continuum emission decreases and an increase in UBV magnitudes will be observed. After the outburst, material is transferred into the disk and a more extended circumstellar disk should be formed, which produces the stronger Hα emission from the system. The new disk material might be ejected from the star by the subsequent mass ejection or reaccreted into the inner region after the supply of material from the star to the disk has been turned off (Clark *et al.* (2001)).

4. Conclusions

The anti-correlation between the optical brightness and the intensity of the Hα emission in the Be/X-ray binaries could be explained by the mass ejections from the Be star. The mass ejection could also trigger the following X-ray outbursts.

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