The disk-fed formation in supergiant of high-mass X-ray binaries

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Abstract: We study the nine of high-mass X-ray binaries with supergiant companions to demonstrate their distribution and evolution. In our model, correlations between mass-loss rate and wind velocity are found and may be tested in further observations. We examine the parameter space where wind accretion is allowed, avoiding the barrier of rotating magnetic fields, with robust data on the magnetic flux of neutron stars. Our model shows that the majority sources (six of nine systems) are often fed by the wind with relatively slow velocity, and this result's according to previous predictions. this is able to provide information about the evolutionary tracks of varied sorts of binaries, and thus exhibit a transparent dichotomy behavior in wind-fed X-ray binary systems.

INTRODUCTION: High mass X-ray binaries (HMXBs), with inferred magnetic fields on the surface of the compact companion of B ∼ 1012 G, are composed of two subclasses: Be X-ray binaries (∼ % 80) in the Galaxy (e.g. van den Heuvel 2004; Taani 2016), with orbital periods ranging from ∼15 days to several years, and with relatively low mass companions (∼ 8 to 20M⊙). In contrast, the second group of HMXBs is the supergiant (SG) sources. They consist of OB SG mass donors (∼ 18 to over 40M⊙) and a compact object accreting from the strong stellar wind with short orbital periods (≤ 11 days) like Cen X-1 and Vela X-1. This group only has about a dozen known members (see e.g. Bhattacharya & van den Heuvel 1991; Taani et al. 2012b,a; Taani et al. 2017; Dai et al. 2017; Karino et al. 2019). Several disk-fed models have been proposed to explain the disk accretion mechanism, including a circumstellar disk (see i.e. Shakura et al. 2012; Taani et al. 2019). One of the most accepted models about properties of the stellar wind is the quasi-spherical accretion of captured matter from the stellar wind of the star.

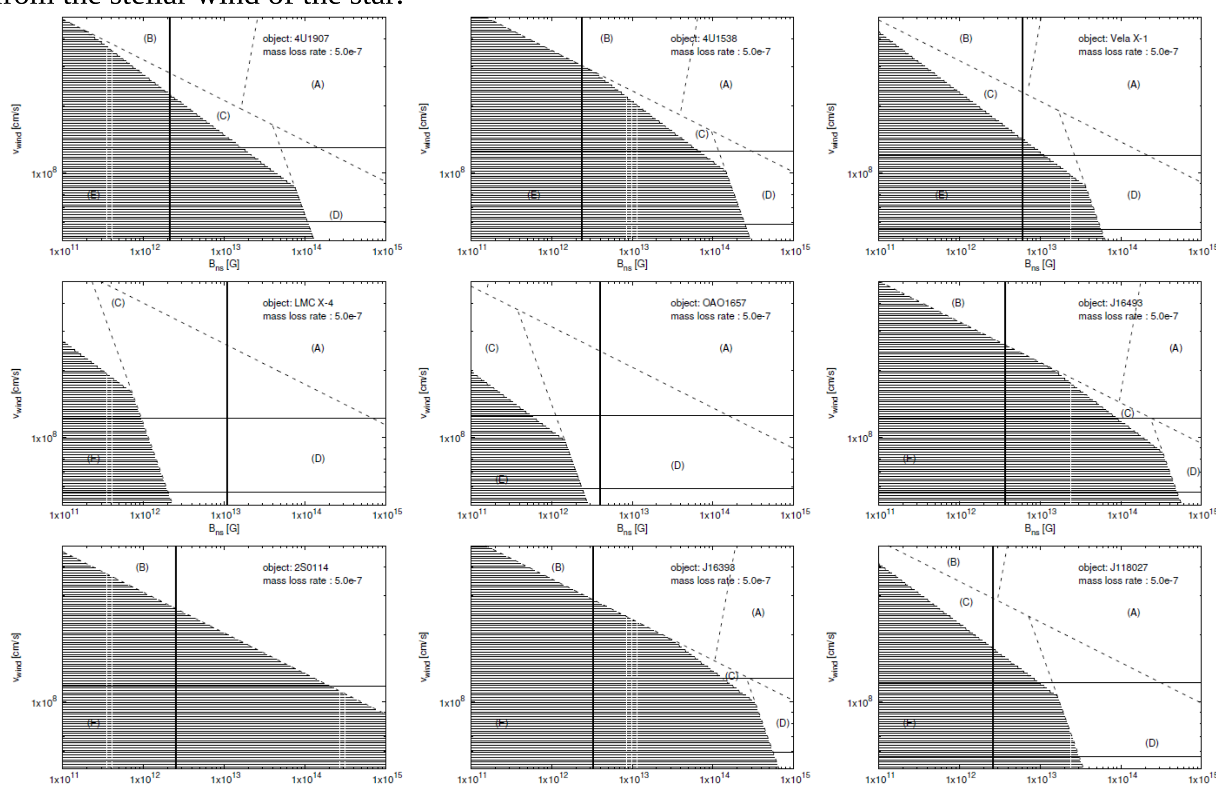

Fig.1: The accretion regime in the wind velocity-mass loss rate space for different systems. The *shaded region* labeled as (E) indicates the direct accretion regime where an HMXB can be observed as a bright X-ray source. The two *horizontal lines* represent high (1500 kms^{-1}) and low (700 kms^{-1}) terminal velocity: v_∞. The *vertical line* shows the derived magnetic field from cyclotron lines. If the region is being bounded by the vertical line with two *horizontal lines* (in the *shaded region*), the system can be understood with the standard wind-fed scenario of SG-HMXB.

THEWIND MODEL

According to equation (2) in Karino & Miller 2016 (KM16), we apply the equilibrium period equation (the magnetospheric radius is equal to the NS corotation radius, $r_m=r_{co}$), where disk accretion is assumed (Bhattacharya & van den Heuvel 1991). It is determined by the long term averaged mass accretion rate (Tong 2015), thus it is convenient for the wind accretion calculation. The magnetic field strength of the NS can be estimated by

$$B_{\rm NS} = 2.184 \times 10^{12}{\rm G} \times \zeta^{1/2} \times \left(\frac{\dot{M}}{10^{18}{\rm g\,s^{-1}}}\right)^{1/2} \left(\frac{P_{\rm s}}{1{\rm s}}\right)^{7/6} ,$$

where we assume that the mass of the NS is $1.4M_\odot$ and radius of the NS is 10 km; for wind accretion (μ ≈ 1) or disk accretion (μ≈ 0.1). We adopt the standard Castor et al. (1975) formula for wind velocity v_w, which assumes a stationary, homogeneous and spherically symmetric outflow

$$v_{\rm w} = v_\infty \left(1 - \frac{R_{\rm d}}{a}\right)^\beta .$$

CONCLUSIONS

We demonstrate that six of nine systems show good agreement with the standard wind-fed scenario. They are 4U1907, 4U1538, J16493, 2S0114, J16393 and J18027. Additionally, Vela X-1 satisfies our constraint in the $v_{wind} - B_{field}$ plane with $\dot{M} \leq 5\times10^{-7} M_\odot\ yr^{-1}$. We assume that the mass-loss rate is reasonably high ($\dot{M} \sim 10^{-6} M_\odot\ yr^{-1}$). As a result, the wind velocity would be limited below $1000 kms^{-1}$. This result is consistent with the recent result given by Gim´enez-Garc´ıa et al. (2016).On the other hand, two systems (LMC X-4 and OAO 1657) cannot satisfy the wind-fed condition, since the reasonable band-region of v_∞ cannot cross the observed B_{field} in the direct accretion regime. Furthermore, we have found that the range between 10^{-7} and $10^{-5} M_\odot\ yr^{-1}$ represents the critical value of the disk to be formed in wind-fed X-ray binary systems. This range seems to be reasonable from a standard mass loss theory of SG systems.

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