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Constraints on mass ejection in black hole formation derived from black-hole X-ray binaries far from the Galactic plane

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Abstract.
The black-hole X-ray binaries SAX J1819.2+2525, XTE J1118+480 and V2107 Oph have relatively large distances to the Galactic plane. Using an estimate of the Galactic potential we compute the minimum space velocity that these systems must have had to arrive at their current position. Assuming symmetric supernova explosions we derive limits on the amount of mass that must have been ejected in order to give the systems the required velocity. For SAX 1819 we find that about 40% of the pre-SN mass must have been ejected. For the other two systems an even higher fraction was ejected, if their velocity is caused by a symmetric supernova.

1. Introduction and Method

There is increasing observational evidence that in events in which black holes are formed, mass is ejected (Israelian et al. 1999, Orosz et al. 2001). Indirect evidence from the observed space velocities of black-hole X-ray binaries also points to substantial mass loss (Nelemans et al. 1999). Here we present a similar investigation for systems with a current position far from the Galactic plane (SAX J1819.2-2525, XTE J1118+480 and V2107 Oph all have $|z| \sim 1$ kpc). To have reached these positions they must have had a certain velocity which we then use to estimate the amount of mass loss in the supernova.

To find the minimum space velocities that the three binaries must have received at the supernova explosion, we calculated orbits in the Galaxy using an axi-symmetric multi component model, as derived by Lorimer (1994, in the implimentaton of Hartman et al 1997). The amount of mass loss in the supernova *assuming a symmetric explosion* is calculated using the method described in Nelemans et al. 1999, taking into account a possible evolution during the X-ray bright phase of the binaries.

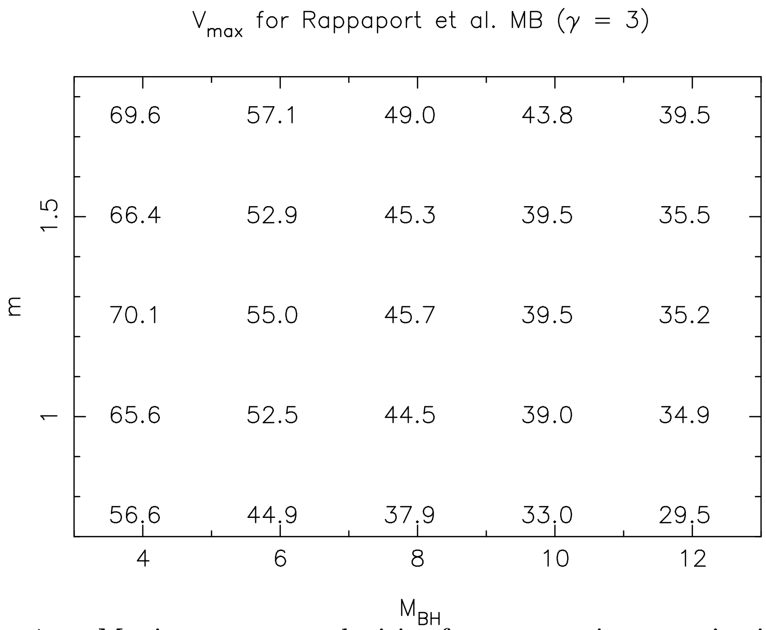

Figure 1. Maximum space velocities for symmetric mass ejection in the supernova as function of the mass of the black hole and its companion. The velocities are calculated such that the companion did not fill its Roche lobe before the supernova and that the X-ray phase starts on the main sequence of the companion and within 10 Gyr.

2. Results

The minimum velocity which SAX J1819.3-2525 must have had just after the supernova is ∼65 km s^{-1}. With the best estimate of the masses of the system taken from Orosz et al. 2001, this implies that for a present black hole mass of 8.73 $M_\odot$ at least 5.9 $M_\odot$ must have been ejected to produce the minimum space velocity. For a black hole of 11.7 $M_\odot$ at least 8.9 $M_\odot$ must have been ejected.

Because the observed X-ray binaries with low-mass donors probably have experienced severe orbital evolution since the supernova we calculate the the maximum velocity that these systems can have obtained from symmetric mass loss for different combinations of black hole mass and donor mass after the supernova (Fig. 1). For the magnetic braking we assumed the form of Rappaport et al. (1983) as modified by Kalogera & Webbink (1998). We find an upper limit around 70 km s^{-1}. The required velocities for XTE J1118+480 and V2107 Oph are of the same order, so we are for the moment unable to conclude whether symmetric mass ejection is sufficient to explain the positions of these systems far from the Galactic plane.

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