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Understanding Compact Object Formation and Natal Kicks. III. The case of Cygnus X-1

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In recent years, accurate observational constraints become available for an increasing number of Galactic X-ray binaries. Together with proper motion measurements, we could reconstruct the full evolutionary history of X-ray binaries back to the time of compact object formation. In this paper, we present the first study of the persistent X-ray source Cygnus\;X-1 that takes into account of all available observational constraints. Our analysis accounts for three evolutionary phases: orbital evolution and motion through the Galactic potential after the formation of black hole (BH), and binary orbital dynamics at the time of core collapse. We find that the mass of the BH immediate progenitor is $15.0 - 20.0$ M$_\sun$, and at the time of core collapse, the BH has potentially received a small kick velocity of ≤ 77 km s^{-1} at 95% confidence. If the BH progenitor mass is less than ~ 17 M$_\sun$, a non zero natal kick velocity is required to explain the currently observed properties of Cygnus\;X-1. Since the BH has only accreted mass from its companion's stellar wind, the negligible amount of accreted mass is impossible to explain the observationally inferred BH spin of $a_* > 0.95$, and the origin of this extreme BH spin must be connected to the BH formation itself. Right after the BH formation, we find that the BH companion is a $19.8 - 22.6$ M$_\sun$ main sequence star, orbiting the BH at a period of $4.7 - 5.2$ days. Furthermore, recent observations show that the BH companion is currently super-synchronized. This super-synchronism indicates that the strength of tides exerted on the BH companion should be weaker by a factor of at least two compared to the usually adopted strength.

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