

numbers, its mass M and its specific angular momentum or spin $a = J/cM$, where J is the BH angular momentum and c is the speed of light. The spin value is conveniently expressed in terms of a dimensionless spin parameter, $a_* = a/R_g$, where the gravitational radius is $R_g \equiv GM/c^2$. The mass simply supplies a scale, whereas the spin changes the geometry. The value of a_* lies between 0 for a Schwarzschild hole and 1 for a maximally-rotating Kerr hole. A defining property of a BH is its event horizon, the immaterial surface that bounds the interior region of space-time that cannot communicate with the external universe. The event horizon, the existence of an innermost stable circular orbit (ISCO), and other properties of BHs are discussed in many texts (e.g., Shapiro & Teukolsky 1983; Kato et al. 1998). The radius of the event horizon of a Schwarzschild BH ($a_* = 0$) is $R_S = 2R_g = 30 \text{ km}(M/10M_\odot)$, the ISCO lies at $R_{\text{ISCO}} = 6R_g$, and the corresponding maximum orbital frequency is $\nu_{\text{ISCO}} = 220 \text{ Hz}(M/10M_\odot)^{-1}$. For an extreme Kerr BH ($a_* = 1$), the radii of both the event horizon and the ISCO (prograde orbits) are identical, $R_K = R_{\text{ISCO}} = R_g$, and the maximum orbital frequency is $\nu_{\text{ISCO}} = 1615 \text{ Hz}(M/10M_\odot)^{-1}$.

2 A Census of Black-Hole Binaries and Black-Hole Candidates

Following the discovery of Cygnus X-1, the second BHB to be identified was LMC X-3 (Cowley et al. 1983). Both sources are persistently bright in X-rays, and their secondaries are massive O/B-type stars (White et al. 1995). The third identified BHB, A 0620-00, is markedly different (McClintock & Remillard 1986). A 0620-00 was discovered as an X-ray nova in 1975 when it suddenly brightened to an intensity of 50 Crab¹ to become the brightest nonsolar X-ray source ever observed (Elvis et al. 1975). Then, over the course of a year, the X-ray nova decayed back into quiescence to become a feeble ($1 \mu\text{Crab}$) source (McClintock et al. 1995). Similarly, the optical counterpart faded from outburst maximum by $\Delta V \approx 7.1 \text{ mags}$ to $V \approx 18.3$ in quiescence, thereby revealing the optical spectrum of a K-dwarf secondary.

As of this writing, there are a total of 20 confirmed BHBs and, remarkably, 17 of them are X-ray novae like A 0620-00. They are ordered in the top half of Table 1 by right ascension (column 1). Column 2 gives the common name of the source (e.g., LMC X-3) or the prefix to the coordinate name that identifies the discovery mission (e.g., XTE J, where a “J” indicates that the coordinate epoch is J2000). For X-ray novae, the third column gives the year of discovery and the number of outbursts that have been observed. The spectral type of the secondary star is given in column 4. Extensive optical observations of this star yield the key dynamical data summarized respectively in the last three columns: the orbital period, the mass function, and the BH mass. Additional data on BHBs are given in Tables 4.1 & 4.2 of McClintock & Remillard (2006).

An observational quantity of special interest is the mass function, $f(M) \equiv P_{\text{orb}} K_2^3 / 2\pi G = M_1 \sin^3 i / (1+q)^2$ (see Table 1, column 6). The observables on the left side of this equation are the orbital period P_{orb} and the half-amplitude of the velocity curve of the secondary K_2 . On the right, the quantity of greatest interest is M_1 , the mass of the BH primary (given in column 7); the other parameters are the orbital inclination angle i and the mass ratio $q \equiv M_2/M_1$, where M_2

¹1 Crab = $2.43 \times 10^{-9} \text{ erg cm}^{-2} \text{ s}^{-1} \text{ keV}^{-1} = 1.00 \text{ mJy}$ (averaged over 2–11 keV) for a Crab-like spectrum with photon index $\Gamma = 2.08$; Koyama et al. (1984).