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Binary black hole mergers: astrophysics and implications for space-based gravitational-wave detectors

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Massive black holes (MBHs) can be found at the centers of nearly all galaxies. When galaxies merge, the black holes form a binary, which eventually coalesces due to the emission of gravitational waves. The final merger is a complicated process which can only be understood by numerically integrating Einstein's equations of general relativity. For many years, this was an impossible task; however, breakthroughs in 2005 and 2006 led to the first evolutions of binary black hole spacetimes through the merger process. Far from being esoteric results interesting only to hardcore relativists, these simulations have turned out to be very important for astrophysics. For example, if the gravitational waves are emitted asymmetrically, conservation of momentum implies that the resulting black hole will experience a recoil or "kick." Numerical studies have shown that in some configurations, the kick can reach values as large as ~ 5000 km/s. The simulations also allow the final spins of the black holes to be calculated. In the future, astrophysical information about coalescing MBH binaries will be obtained by directly measuring the gravitational waves with space-based detectors. In this case, the inclusion of accurate merger and ringdown waveforms into the signal model allows for significant improvement in measuring system parameters like mass, spin, and luminosity distance.