Hydrodynamical Neutron Star Kicks in Three Dimensions

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Using three-dimensional (3D) simulations of neutrino-powered supernova explosions we show that the hydrodynamical kick scenario proposed by Scheck et al. on the basis of two-dimensional (2D) models can yield large neutron star (NS) recoil velocities also in 3D. Although the shock stays relatively spherical, standing accretion-shock and convective instabilities lead to a globally asymmetric mass and energy distribution in the postshock layer. An anisotropic momentum distribution of the ejecta is built up only after the explosion sets in. Total momentum conservation implies the acceleration of the NS on a timescale of 1-3 seconds, mediated mainly by long-lasting, asymmetric accretion downdrafts and the anisotropic gravitational pull of large inhomogeneities in the ejecta. In a limited set of 15 solar-mass models with an explosion energy of about 10^51 erg this stochastic mechanism is found to produce kicks from <100 km/s to >500 km/s, and >1000 km/s seem possible. Strong rotational flows around the accreting NS do not develop in our collapsing, non-rotating progenitors. The NS spins therefore remain low with estimated periods of about 500-1000 ms and no alignment with the kicks.

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