Joint Institute for Nuclear Astrophysics

Results from Core-Collapse Simulations with Multi-Dimensional, Multi-Angle Neutrino Transport

Brandt et al. (2010) presented new results from the only 2D multi-group, multi-angle calculations of core-collapse supernova evolution. The first set of results from these calculations was published in Ott et al. (2008). They followed a nonrotating and a rapidly rotating 20-solar-mass model for ~400 ms after bounce and showed that the radiation fields vary much less with angle than the matter quantities in the region of net neutrino heating. This happens because most neutrinos are emitted from inner radiative regions and because the specific intensity is an integral over sources from many angles at depth. The latter effect can only be captured by multi-angle transport. They then computed the phase relationship between dipolar oscillations in the shock radius and in matter and radiation quantities throughout the postshock region. They demonstrated a connection between variations in neutrino flux and the hydrodynamical shock oscillations, and used a variant of the Rayleigh test to estimate the detectability of these neutrino fluctuations in IceCube and Super-K. Neglecting flavor oscillations, fluctuations in our nonrotating model would be detectable to ~10 kpc in IceCube, and a detailed power spectrum could be measured out to ~5 kpc. These distances are considerably lower in our rapidly rotating model or with significant flavor oscillations. Finally, they measured the impact of rapid rotation on detectable neutrino signals. Their rapidly rotating model has strong, species-dependent asymmetries in both its peak neutrino flux and its light curves. The peak flux and decline rate show pole-equator ratios of up to ~3 and ~2, respectively.

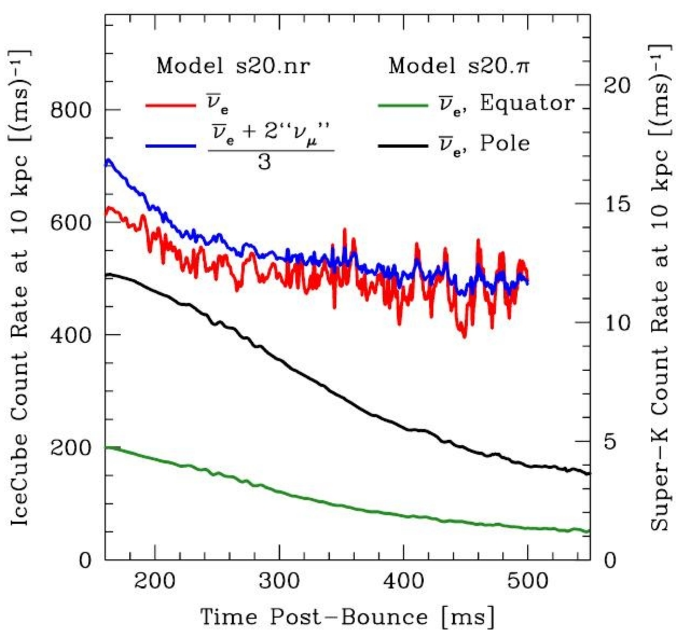

Figure 4. Estimated $\overline{\nu}_e$ signals (Equation (7)) and fully mixed signals $1/3\,\overline{\nu}_e + 2/3``\nu_\mu''$ of our nonrotating model and $\overline{\nu}_e$ "signals" of our rapidly rotating model. The fractional fluctuations are as high as 10% in the nonrotating model, but $\lesssim$2% in the rotating case. To the extent that neutrino flavor mixing does occur, smoothly declining "ν_μ" will dilute the rapid fluctuations shown here in $\overline{\nu}_e$.

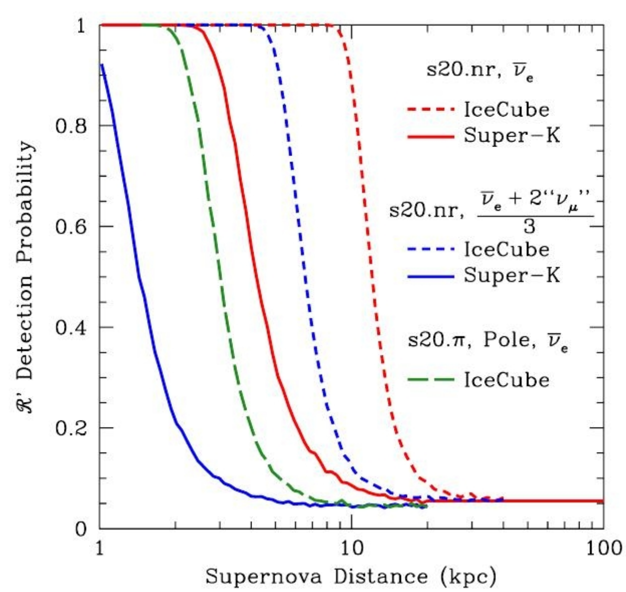

Figure 5. Probability of a 2σ detection of at least one rapidly varying component of the neutrino luminosity using the modified Rayleigh test (Equation (9)) on Monte Carlo realizations of the estimated signals in $\overline{\nu}_e$ and $1/3\,\overline{\nu}_e + 2/3``\nu_\mu''$ shown in Figure 4. Depending on the extent of neutrino mixing, rapid neutrino fluctuations in our nonrotating model may be detectable by IceCube as far away as ~10 kpc. High-frequency fluctuations would be detectable by IceCube only within ~3 kpc even under the optimistic assumption that no flavor mixing occurs.

T.D. Brandt, A. Burrows, & C.D. Ott, Astrophys. J., 728, 8, 2011 (arXiv:1009.4654)