APR15-2015-000752

Abstract for an Invited Paper
for the APR15 Meeting of
the American Physical Society

The Critical Neutrino Luminosity of the Core-Collapse Supernova Explosions

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All massive stars end their lives with core collapse and many as supernova explosions. Despite observations of thousands of supernovae, detailed numerical calculations and theoretical efforts, the mechanism of explosion is poorly understood. In the most-investigated "neutrino explosion mechanism," the collapse turns into explosion when the neutrino luminosity from the proto-neutron star exceeds a critical value $L_{\rm crit}$. I will explain the connection between the steady-state isothermal accretion flows with bounding shocks and the neutrino mechanism, and present a new "antesonic" explosion condition, which characterizes the transition to explosion over a broad range in accretion rate, proto-neutron star properties and microphysics. The formalism of the critical neutrino minosity offers a convenient way to qualitatively investigate the importance of individual physical effects and progenitor structure on the outcomes of the core collapse. I will briefly review the importance of multi-dimensional effects and collective neutrino oscillations. Finally, by parameterizing the systematic uncertainty in the explosion mechanism and by using spherical quasi-static evolutionary sequences for many hundreds of progenitors over a wide range of metallicities, I will show how the explosion threshold maps onto observables - fraction of successful explosions, remnant neutron star and black hole mass functions, explosion energies, nickel yields - and their mutual correlations. Successful explosions are intertwined with failures in a complex but well-defined pattern that is not well described by the progenitor initial mass and other supernova properties show a similar pattern.