Astrophysics Roadmap (Due Monday, March 25, 2013)

Future astrophysics unified simulations

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The work plan proposed here is expected to have a major impact in several areas. The proposed studies will advance our fundamental understanding of the environments of collapsing and merging stars, and extend to other astrophysical systems, such as microquasars and AGN, in which jetted outflows and special/general relativity play an important role. Solving the Einstein equations and nucleosynthesis, fundamental microscopic physical processes such as neutrino need to be investigated. Recently full (dynamic metric) GRMHD simulations have been greatly developed. However, MHD is mainly ideal and resistive full GRMHD calculation is being developed.
In order to include kinetic processes, particle-in-cell simulations need to be coupled with Einstein equations. Static RPIC code has been developed Watson & Nishikawa (2010), this code needs to be extended to dynamic metric solver. One of other extension will be the capability of handling quark-gluon plasma with quantum effects in order to simulate neutron stars. For the research of cosmological plasma we need to handle dark matter and dark energy in a new code.

The project needs to provide a major leap forward in the computation and simulation of complex charged and neutral gas systems. The development of codes that embrace "coupling complexity" via the self-consistent incorporation of multiple physical scales and multiple physical processes in models is viewed as a pivotal development in the different plasma physics areas for the current decade.

Proposed project should study high energy processes associated with the accretion onto compact objects, massive star core collapse, neutron star and black hole mergers and relativistic interaction of stellar winds with the interstellar medium. The observed asymmetries in some Type II supernovae and highly beamed emission inferred for GRBs suggest that fast, highly collimated outflows are created in the vicinity of black holes resulting from stellar collapse- or merger events. Rapidly rotating core collapse supernovae (ccSNe) are the leading model for the central engines of long duration GRBs, and have been studied using realistic equations of state, neutrino cooling and heating processes, nucleosynthesis, and self-gravity, but mainly in the frame of nonrelativistic hydrodynamics. Despite much progress, the question of how ccSNe and collapsars work has not yet been fully answered. This 10-year research project needs to develop state-of-the-art relativistic codes to obtain breakthrough results relevant to the formation and evolution of jetted outflows with the emphasis on the microphysics of particle acceleration processes that provide the ultimate link to observations via their associated radiative losses.