BACCA: Bay Area Center for Computational Astrophysics

Program Areas: Astrophysics and cosmology, computations, nuclear physics, hydro-dynamics, black hole physics, radiation transport, mission design (LSST, JDEM), supernova observations, software development, training and education.

Principal Investigator: Stan Woosley – University of California Santa Cruz
(831) 459-2976; woosley@ucolick.org; FAX (831) 459-5265

Co-Proposing Institutions: UC Santa Cruz, LLNL, LBNL

Principal Co-I's: UCSC – faculty members Piero Madau, Joel Primack, and Enrico Ramirez-Ruiz; Hubble Fellow Dan Kasen; LLNL - Peter Anninos, Louis Howell, Rob Hoffman, Scott Olivier, Jay Salmonson; LBNL – John Bell, Peter Nugent

Total Budget: $1.05 M/yr for three years

Summary: The goal of this Center is to bring together the necessary expertise in applied mathematics, computer sciences, astrophysics, cosmology, and astronomy to constitute the world's leading center in high-energy computational astrophysics. The Center builds on LLNL's traditional strengths in hydrodynamics, radiation transport, nuclear physics, computations and it's historical interest in supernovae, nucleosynthesis, and compact objects. Two major codes, *COSMOS++* and *CASTRO* will be further developed (both already exist in an advanced operational state) and applied to problems in supernova physics, gamma-ray bursts, black hole physics, active galaxies, and cosmology. The supernova models will be post-processed for their nucleosynthesis, and multi-dimensional light curves and spectra will be computed and compared against observations. The latter will be used to help plan mission strategy for the Large Synoptic Survey Telescope (LSST) and the Joint Dark Energy Mission (JDEM). Both are receiving DOE investment. Calculations will use the computational resources of LLNL (especially ATLAS), if time is awarded. If not, time will be applied for at NERSC and ORNL. Code development will occur on local "super-mini's" that already exist. Nucleosynthesis studies will use nuclear data measured, compiled, and computed at LLNL. The development and application of the codes and the testing of results against observations provides ample research opportunities for three post-docs and four graduate students.

Participants by Institution and Budget: One-third of the budget is for LLNL scientists. Adequate funding at LLNL is essential for any true collaboration to exist. Given the overhead rates, the funds requested are adequate to support five lab personnel at a maximum of 20% time (one or two will be at 10%). This much time is needed for the project goals to be fully realized, but a larger amount might interfere with their programmatic duties. 50% of the funds are for graduate students and postdocs and 15% is for faculty summer salary (1 mo each) at UCSC and visitors. All numbers below are fully burdened with overhead.

- UCSC (700 k/yr) - Stan Woosley (PI), Piero Madau, Joel Primack, Enrico Ramirez-Ruiz (summer salary total 175 k/yr), 3 postdocs (300 k/yr), 4 graduate students (200 k/yr), visitors (25 k/yr)

- LBNL (0 k/yr) – Peter Nugent will aid in supervising one of the UCSC graduate students to work on issues relevant to JDEM and LSST development (along with Olivier at LLNL). John Bell will partially supervise 1 postdoc to work on *CASTRO* code development with Howell and Woosley.

- LLNL (350 k/yr) – Peter Anninos, Louis Howell, Rob Hoffman, Scott Olivier, Jay Salmonson

Management and Operation: - Because all members are in the Northern California Bay area (within a 1.5 hour drive of LLNL), it is possible and expedient to have a frequent exchange of personnel between campuses. Graduate students and postdocs will be hired at UCSC, though as noted, one grad student and one postdoc will spend significant time at LBNL working on observations of supernovae and *CASTRO* code development respectively. All postdocs will be strongly encouraged to spend at least one month/yr at LLNL. Grad students will be encouraged to spend their summers there. Faculty co-I's will also spend approximately 1 mo/yr at LLNL. Conversely, visits to UCSC by LLNL collaborators will be encouraged, though we are aware that programmatic needs may limit this. We expect two major group meetings per year with the site alternating among the three sites. Smaller group meetings will occur more frequently.

Postdocs and students will thus have the opportunity to work with leading experts in their field on various campuses and with astrophysicists, observers, and code developers. BACCA will not only develop the next generation of codes, but train the next generation of computational scientists. We expect that LLNL will attract some of these.

Scientific focus: Research will focus on a better understanding, achieved through large-scale computation, of a) explosive phenomena in astrophysics, and b) massive black hole formation and interactions in the context of cosmic structure formation. By a), we mean all kinds of supernovae, both Type Ia and II, and gamma-ray bursts – their mechanisms, nucleosynthesis, light curves and spectra. The understanding of light curves and spectra gained will be used to plan strategy for ground and space-based observations. LLNL was once at the forefront of supernova and GRB modeling. This science has expanded in the meantime and now touches on almost all aspects of modern astrophysics. Topic b) has common needs with topic a) for codes, computer time, and lab expertise. Masses of central black holes are observed to correlate with their host galactic spheroid properties, and the energy released in their merging and accretion must play a crucial role in galaxy evolution.

Code development*: CASTRO* – 3D adaptive-mesh, multi-energy-group flux-limited diffusion (MGFLD) code being developed by Howell, Singer, Bell, and Almgren. *COSMOS++* - 3D general relativistic, magnetohydrodynamic code with multi-group flux-limited diffusion and unstructured mesh – developed by Fragile, Anninos and Salmonson. *SUNRISE* – Monte Carlo radiative transport code developed by Primack's postdoc Jonsson, to be included in COSMOS++. *SEDONNA* – 2D and 3D implicit Monte Carlo code for radiation transport and spectrum calculation – developed by Kasen.

A separate proposal for the massive black hole aspects of this proposal will be submitted by Madau. In the event that this BACCA proposal is funded, the black hole proposal would be withdrawn.