

Los Alamos National Laboratory
Los Alamos Astrophysics
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The following review presents a set of highlights of the astrophysics work at Los Alamos National Laboratory covering the work from October 2003 through September 2004.

1. FOREWORD

Astrophysics at Los Alamos National Laboratory (LANL) covers a range of disciplines, groups, and divisions. As astrophysics is not an official “mission” of the laboratory, very few staff-scientists work full-time on astrophysics. However, LANL boasts over 50 scientists spending >15% of their time working on astrophysics. Many more scientists had dissertation topics in astrophysics and are now working on projects related to national security. Astrophysicists are trained in many of the skill requirements for these projects and make ideal scientists for LANL “mission” projects. Astrophysics also serves LANL by highlighting both instrument and computational advances at the lab. For both these reasons, astrophysics plays a continued and vibrant role at LANL.

2. SCIENTIFIC ACCOMPLISHMENTS OCT. 2003 – SEPT. 2004

2.1 Theoretical Astrophysics

Theoretical Astrophysics at LANL remains dominated by numerical calculations. Scientists at LANL, collaborating with astrophysicists across the world, are using numerical techniques to model a wide range of astrophysical phenomena. These modeling efforts include asteroid impacts, planet formation and spectra of planets, stellar evolution, x-ray bursts, novae, supernovae, gamma-ray bursts, white dwarf cooling, the merger of compact binaries, the galactic center, black hole accretion disks, primordial dwarf galaxy formation, globular cluster formation and cosmology.

LANL also does extensive work studying the detailed physics necessary for these calculations from hydrogen equations of state, to photon (and neutrino) opacities and equations of state for planets, white dwarfs, and neutron stars. The close ties with other physics disciplines at LANL is one of the leading strengths of LANL astrophysics. One such tie is with the magnetic field community at LANL. A three-year effort to adapt codes developed in the magnetic field community at LANL and develop experiments to test these codes with an eye toward astrophysics is just now starting to bear fruit (e.g. Beckley *et al.* 2003; Colgate *et al.* 2004).

Another connection has been made between the nuclear physics community and the first steps to build a nuclear astrophysics institute at LANL have begun. The astrophysics community is beginning to take advantage of both the nuclear physics theory (e.g. many-body theory, global models) and experimental facilities (LANSCE, DANCE) at LANL. LANL is part of the Joint Institute for Nuclear As-

triphysics (JINA – <http://www.jinaweb.org/>) and, for the second year in a row, has hosted a week-long workshop bringing together nuclear physicists and astrophysicists.

LANL astrophysicists are also taking advantage of LANL expertise to develop computer tools ranging from state-of-the-art Beowulf clusters to distributed disk arrays used to store, and allow quick access to, data (also applicable for the National Virtual Observatory). LANL has begun a 3-year effort to develop data mining and storage techniques adapted toward astrophysics applications.

Research Highlights This Year Planetary and Stellar Astrophysics:

Most (>80%) of the theoretical publications this year have focused on the life and death of stars. This is due, in part, to the new research thrust in the theoretical astrophysics group (T-6). The last 2 hires into this group have centered on this topic and it is likely that this thrust area will grow with time. This topic also has numerous ties to the programmatic aspects of the laboratory (both in physics and computational science) and not only is funding in this area strong, but many of the part-time astrophysicists at the laboratory also come from a planetary/stellar background and work on topics from white dwarf cooling to pulsating stars to stellar collapse and pulsars. Here we briefly discuss some of the results in this field.

Planets, White Dwarfs, and Stellar Evolution: Scientists at LANL have produced models of planet-forming disks around young stars and the equation of state (and opacities) in planets and white dwarfs. Although this effort is currently small, the relevant microphysics may find support in the programmatic arena, allowing it to grow. For example, LANL scientists studied the effect our uncertainty in the behavior of hydrogen at megabar pressures has on Jupiter and Saturn (Saumon & Guillot 2004). Stellar evolution modeling at LANL, on the other hand, takes advantage of the close interaction between stellar and nuclear physics at LANL. An example of such close work is a study of the effects of the $^{14}\text{N}(p,\gamma)^{15}\text{O}$ reaction rate on carbon star formation (Herwig & Austin 2004).

Novae, X-ray Bursts, and Type Ia Supernovae: In collaboration with scientists at the Chicago ASCI Flash center, LANL scientists have studied the thermonuclear explosions in material accreting onto white dwarfs and neutron stars and in the inner cores of white dwarfs. LANL scientists have used both 1-dimensional and multi-dimensional codes to study these astrophysical bombs, increasing the level of sophistication in the models of novae and X-ray bursts. For instance, the multi-zone 1-dimensional models of Type I X-ray bursts (a study including LANL scientists) allowed the study of time evolution of a series of bursts (Woosley *et al.* 2004). These studies allow astronomers to better apply nuclear rates from theory and experiment.

Stellar Collapse Most of the studies of stellar collapse have been a continuation of the 3-dimensional SNSPH simulations (Fryer 2004a, Fryer & Warren 2004, Fryer *et al.* 2004). These studies focused on asymmetries in the collapse, studying their implications on observations of neutrinos, gravitational waves, and neutron star kicks. LANL is also beginning to study the asymmetries in these explosions and their implications on more readily available observables such as photon emission and nucleosynthesis (preliminary results are in Fryer 2004b, Hungerford 2004). LANL is also studying the effect of binaries in stellar collapse from the role of neutron star kicks to the proposal of a supernova/gamma-ray burst mechanism invoking the merger of two white dwarfs (Middleditch 2004). Most of this work also takes advantage of the strong nuclear theory work at LANL (e.g. Reddy 2004) and studies of the role of neutrino interactions and nuclear theory continue at LANL.

2.2 Experimentation and Observations

LANL is involved in several major instrumentation projects with team members from around the world. These instruments include the Sloan Digital Sky Survey, rapid slewing telescopes such as ROTSE and RAPTOR, high energy satellites and ground-based observatories: XMM, HETE, Swift, EGRET, OGLE, Fly's Eye and Milagro. LANL scientists are active in both designing hardware and software for these observatories and in directing the science in these projects. LANL is one of the world leaders in transient observations, developing both rapidly slewing telescopes and software and computational storage to manage rapidly variable data.

Research Highlights This Year

High Energy and Optical Transients:

With their background in transient telescopes and high-energy telescopes, LANL scientists are ideally poised to do a number of studies of Gamma-Ray Bursts. From a series of results obtained with HETE to the individual studies of GRBs in X-rays (XMM) and in the very high energy regimes using EGRET, Fly's Eye, Milagro, LANL scientists have continued to push forward our understanding of these objects. LANL scientists have also been working on software for upcoming missions like Swift to quickly detect and localize bursts (Fenimore *et al.* 2004).

Analyzing and managing data from rapidly varying objects is one of the major difficulties in studying transients. LANL scientists are at the forefront of this field, actively studying a number of time-dependent phenomena from the optical (e.g. OGLE, ROTSE, and RAPTOR data) to high-energy data from RXTE, XMM and HETE. Some of this work has combined high-energy and optical transients to study the correlation between optical and high-energy variability in compact objects like SS Cygni and LMC X-2 (McGowan *et al.* 2003,2004).

To better do this analysis, LANL scientists have developed a variability database and made this database available to astrophysicists throughout the world (<http://skydot.lanl.gov/>). With this database, astronomers can do

variability studies of transients such as the study by LANL scientists on Mira variables (Wozniak, McGowan & Vestrand 2004).

Sloan Digital Sky Survey and High-Energy Surveys:

Another highlight this year arises from LANL's involvement with survey telescopes. LANL is becoming an increasing part of the Sloan Digital Sky Survey with publications ranging from data releases (Abazajian *et al.* 2004a,b) to studies of cool stars (West *et al.* 2004) and cosmology (Tegmark *et al.* 2004a,b). LANL has also played a role in the Fly's Eye experiment (Abassi *et al.* 2004a,b,c) and Milagro (Atkins *et al.* 2004a,b,c) with studies of cosmic rays, the Crab Nebula and gamma-ray bursts.

3. CONFERENCES SUPPORTED BY LANL

LANL supports a number of astrophysics workshops and meetings in New Mexico. Meetings and workshops supported by LANL from October 2003 to September 2004 were:

“SF04 Cosmology Workshop,” July 7-25, Santa Fe, organizer S. Habib (T-8, LANL) <http://t8web.lanl.gov/people/salman/sf04/>.

“Chemical Enrichment of the Early Universe,” August–13, Santa Fe, organizers A. Heger, C. L. Fryer, F. X. Timmes (T-6, LANL), Jim Truran (U. Chicago) <http://qso.lanl.gov/meetings/meet2004/index.html>

PUBLICATIONS

The publication list includes all refereed papers published between October 2003 and September 2004 by the LANL Staff or Postdocs.

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