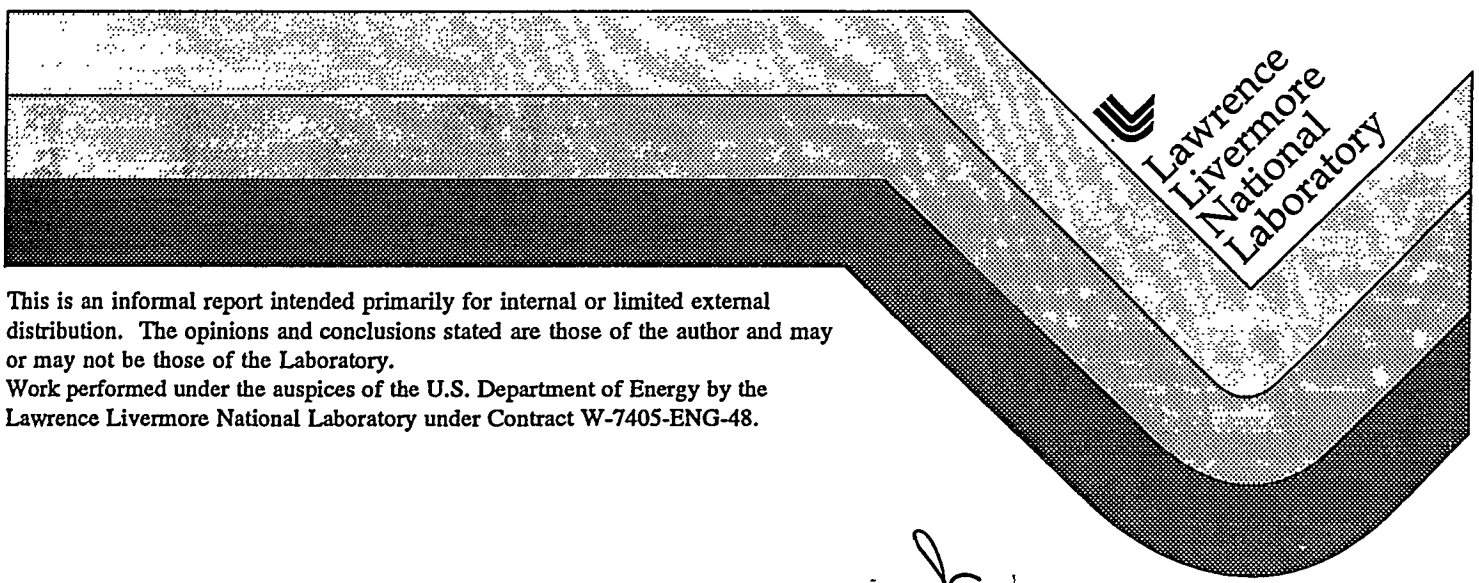
UCRL-ID-123671

Hydrodynamics and Nucleosynthesis in Neutron Stars, Supernovae, and the Early Universe

Grant Mathews

March 1996



Annual Report Contributio

Project Title: **Tracking Code:** 94-ERD-030

Hydrodynamics and Nucleosynthesis in Neutron Stars, Supernovae, and the Early Universe

---

Principal Investigator: Grant Mathews **Employee number:** 574625

Core Competency: Nuclear/Atomic Science & Tech

Annual Report Authors:
Mathews, Grant J.

Annual Report Description: **Character Count:** 4129

In this proposal we apply laboratory expertise in integrated numerical modeling of relativistic hydrodynamics, radiation transport, and thermonuclear reaction rates to forefront areas of basic research in areas of astrophysical interest. These studies include the last stages of a merging neutron-star binary system; the pre-collapse, collapse, and post-collapse evolution of supernova cores; the violent relaxation, protogalactic mergers, and stellar nucleosynthesis associated with galaxy formation and studies of primordial nucleosynthesis during the big bang. This project provides unique high-visibility solutions to current technical problems while enriching current laboratory capabilities in the relevant disciplines.

In FY95 the first systematic computations of instabilities in the final orbits of two neutron stars were completed. A new general relativistic instability was discovered and published in Physical Review Letters (Wilson and Mathews 1995). It was observed that nonlinear effects of the strong graviational fields of the neutron stars cause the stars to separately collapse into individual black holes seconds before the stars actually merge. This surprising result significantly impacts the development of next generation gravity wave detectors and theoretical studies of astrophysical gamma-ray bursts.

We have made a preliminary study of the collapse heating as a source for gamma-ray bursts. We also showed that the mass loss from the stars is too little to contribute to heavy element nucleosynthesis in the Galaxy. This work was the subject of Jim Wilson's 1995 Marcel Grossman Award.

The work on supernova cores has considered effects of weak interaction rates on precollapse structure, phase transitions in nuclear matter during the collapse, and the evolution of material in the neutrino heated baryon wind from the proto-neutron star. We completed and submitted a study of nickel nuclei and calculated electron capture rates for several nuclei which wereadded to our data base of key electron capture and beta rates for stellar collapse. This work has stimulated several experimental projects to test our calculations. We also completed and published a paper (Gentile et al 1995) on the effects of a Q-star equation of state on supernovae. Studies of convection in supernovae have been run but not yet to sufficiently late time.

We studied the evolution of the light elements Li, Be, and B in the halo and disk phase (Yoshii et al 1995) and showed that accretion on to halo stars passing through the galactic disk can mimic a big bang origin. We also studied globular cluster formation in the protogalaxy and the globular cluster metallicity distribution (Lee et al 1995). In separate works, hydrodynamic simulations of three-dimensional cloud mergers were undertaken to

simulate globular cluster formation. An exact scheme for solving the cloud-in-cloud problem in Press Schechter theory (Jedamzik 1995) was also developed. We developed chemical evolution models to study abundance gradients in disk galaxies as a means to constrain the initial mass function for star formation. In a work near completion, we developed a model to explain both the observed microlensing events from the MACHO collaboration, and the observation of hot X-ray gas in galactic clusters. In this model, the microlensing objects are stellar remnants whose ejecta exited the galaxies to become the hot gas of the clusters.

Studies of constraints on primordial isocurvature baryon (PIB) fluctuations were completed and submitted. These studies found new significant constraints which limit this possible cosmological model. New derivations of the upper and lower limits to the universal baryon density were also completed and published (Mathews et al 1995; Jedamzik et al 1995). A new estimate of the primordial helium abundance was derived. A significant review paper of this field was written and submitted (Mathews and Schramm 1995). The new upper limits on the baryon content of the universe may solve some of the questions raised by the MACHO and hot X-ray gas observations.

Student/Post Doc

Project Title: **Tracking Code:** 94-ERD-030

Hydrodynamics and Nucleosynthesis in Neutron Stars, Supernovae, and the Early Universe

---

Student/Post Doc Info...

Year	First Name	Last Name	University Name (if applicable)	Postdoc Status
1994	Karsten	Jedamzik		
1995	Pedro	Marronetti	Notre Dame	

Publications

Project Title: **Tracking Code:** 94-ERD-030

Hydrodynamics and Nucleosynthesis in Neutron Stars, Supernovae, and the Early Universe

Pub Nº	Title	Journal	Vol	Page	Authors	Pub Type
UCRL-JC-117458	Inhomogeneous Primordial Nucleosynthesis and New Abundance Constraints on $/Omega_b$	Astrophysical Hournal			Mathews, G. J.; Kajino, T.; Orito, M.	Refereed publication
UCRL-JC-117487	Absence of a Lower Limit on $/Omega_b$ in Inhomogeneous Primordial Nucleosynthesis	Astrophysical Journal	441	465	Kedamzik, K.; Mathews, G. J.; Fuller, G. M.	Refereed publication
UCRL-JC-118319	A Merger Model and Globular Cluster Formation	Astrophysical Journal	449	616	Lee, S.; Schramm, D. N.; Mathews, G. J.	Refereed publication
UCRL-JC-118388	Beryllium and Boron Nucleosynthesis and New Interstellar Accretion	Astrophysical Journal	447	184	Yoshii, Y.; Mathews, G. J.; Kajino, T.	Refereed publication
	Instabilities in Close Neutron Star Binaries	Phys. Rev. Lett.	75	4161	Wilson, J. R. and Mathews, G. J.	Refereed publication
UCRL-JC-118330	Relativistic Neutron Star Binary Coalescence	World Scientific: Singapore			Wilson, J. R. and Mathews, G. J.	Refereed publication
	Q-Star Equation of State and the Prompt Shock in Supernovae	Physical Review D			Gentile, N. A.; Hughes, J.; and Mathews G. J.	Refereed publication

Awards

Project Title: **Tracking Code:** 94-ERD-030

Hydrodynamics and Nucleosynthesis in Neutron Stars, Supernovae, and the Early Universe

Year	First Name	Last Name	Sponsor
1994	James	Wilson	Int. Center for Rel. Astrophys., Int. Center for Theor. Phys., Int. Sci. Foui

Award

Marcel Grossman Award

Year	First Name	Last Name	Sponsor
1994	Grant	Mathews	American Physical Society

Award

Fellow in Physics