FINAL REPORT
"^{22}Na Decay Gamma Rays From Classical Novae"
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SUMMARY OF RESEARCH ACTIVITIES SUPPORTED IN FULL OR IN PART BY NASA GRANT NAG 5-1565 AT THE UNIVERSITY OF ILLINOIS

NASA Grant NAG 5-1565, at the University of Illinois, has provided support for a program of theoretical research in nuclear astrophysics and related areas, focusing upon the possibility of detection of gamma rays from nearby novae. Particular attention has been given to the evaluation of the theoretical expectations for gamma ray emission from four possible sources: (1) the positron decays of the unstable CNO and fluorine isotopes that are transported to the surface regions of the envelope in the earliest stages of the outbursts; (2) ^{7}Be decay gamma rays; (3) ^{22}Na decay gamma rays released in the later stages of the outbursts; and (4) ^{26}Al decay gamma rays from novae and their possible contributions to Galactic emission. The critical questions of (i) the frequency of occurrence of ONeMg-enriched novae; (ii) the expected Galactic distribution of the novae that produce ^{26}Al; and (iii) the nature of the observed soft X-ray emission from classical novae, have also been addressed. Considerable progress in research has been achieved on many of these fronts. Researchers who have received some level of support from this grant include the Principal Investigator, James W. Truran, Sumner Starrfield, Ami Glasner, Anurag Shankar, and John Hayes. Brief summaries of the results of several research projects are presented below.

Powering the Light Curves of Fast Classical Novae

Observations of fast classical novae indicate the existence of a large and serious disagreement with theory, regarding the maximum luminosities achieved by these systems. Fast novae in our Galaxy, and those in M-31 and the LMC (for which distances are particularly well determined), reach absolute visual magnitudes as bright as -8.5 and can remain brighter than -7 for several days. This behavior has not been successfully reproduced by any self-consistent, time-dependent numerical simulation. Hayes and Truran (1994) have demonstrated that existing numerical models are energetically capable of powering such observed emission for the requisite timescale, and argue that the discrepancy arises due to the fact that the physics describing the exchange of energy and momentum between the material and radiation has been oversimplified in the hydrodynamical studies published to date. Efforts are currently underway to remedy this situation, by substantial modification of the numerical procedures utilized in our hydrodynamic program.

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Abundances in Nova Ejecta

Livio and Truran (1994) have re-examined the question of the frequency of occurrence of oxygen-neon-magnesium (ONeMg) degenerate dwarfs in classical nova systems, in light of recent observations which have been interpreted as suggesting that "neon novae" can be associated with relatively low mass white dwarfs. Determinations of heavy element concentrations in nova ejecta were reviewed, and possible interpretations of their origin were examined. We concluded that, of the eighteen classical novae for which detailed abundance analyses are available, only two (or possibly three) seem unambiguously to demand the presence of an underlying ONeMg white dwarf: V693 CrA 1981, V1370 Aql 1982, and possibly QU Vul 1984. Three other novae which exhibit significant neon enrichments, relative to their total heavy element concentrations, are RR Pic 1925, V977 Sco 1989, and LMC 1990 #1. This result is entirely consistent with present frequency estimates, and our interpretation of the lower levels of enrichment in other systems explains, in a natural way, the existence of relatively low mass white dwarfs in some of the "neon" nova systems.

The Nature of the Soft X-Ray Emission from GQ Muscae

Ögelman *et al.* (1993) have recently reported the detection of Nova GQ Muscae 1983 at soft x-ray wavelengths, nine years after outburst, with the ROSAT satellite. The observed spectrum is very soft, and is generally consistent with black body emission from a $\sim M_{\odot}$ white dwarf, burning at a near Eddington luminosity and an effective temperature $\sim 3.4x10^5$ K. Such a soft x-ray signature is entirely consistent with expectations for the long term evolution of classical novae in outburst (MacDonald, Fujimoto, and Truran 1985), as it can arise as a natural consequence of the hardening of the radiation from novae, as the photospheric radius decreases during an extended phase of shell hydrogen burning at approximately constant bolometric luminosity. Truran, Glasner, and Hayes (1994), in a paper soon to be submitted for publication: (1) review and discuss the observations of Nova GQ Muscae, the prototype event of this nature, (2) present recent calculations which allow us better to understand the timescales for the onset and duration of the observed phase of soft x-ray emission, and (3) address the obvious question as to why it is that GQ Muscae is one of only a few of the recent classical novae to have been found to exhibit this behavior.

Nucleosynthesis Associated with ONeMg Enriched Novae

Detailed calculations have been performed of the nucleosynthesis that accompanies the occurrence of thermonuclear outbursts on ONeMg white dwarfs (Politano *et al.* 1995). The trends in the production of the gamma ray sources ^{23}Na and ^{26}Ali, as a function of the mass of the white dwarf have also been identified. Careful attention is being given to the interpretation of the abundance observations of novae, in lieu of the fact that there appears to be an inconsistency: the large masses of the ejected shells that have been inferred from observations of several recent such "neon novae" are inconsistent with the large masses expected from theory for the ONeMg white dwarfs on which such outbursts are expected to occur. Revised rates for a number of important thermonuclear reactions for ^{23}Na and ^{26}Al production have been included, which allow more realistic predictions of the emerging abundances.

PUBLICATIONS
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"Gamma Rays from Classical Novae"
AT THE UNIVERSITY OF ILLINOIS 1991-1994

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