FUSE Observations of Galactic and LMC Novae in Outburst
Final Report—Summary of Research
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Analyzing FUSE Observations of Galactic and LMC Novae

We have started to analyze the FUSE data of novae obtained under this program with improved expanding NLTE line-blanketed model atmospheres. The new models are still under construction, however, initial results are very promising. We expect that these models will be useful not only for the analyses of FUSE nova spectra but also for the interpretation of FUSE spectra of stellar winds, hot stars, and other objects.

Detailed NLTE Model Atmospheres for Novae during Outburst:
II. Modeling optical and ultraviolet observations of Nova LMC 1988 #1.
with Greg J. Schwarz, S. Starrfield, E. Baron, France Allard, Steven N. Shore, P. Whitelock

LMC 1988 #1 was a slow, CO type, dust forming classical nova. It was the first extragalactic nova to be observed with the IUE satellite. We have successfully fitted observed ultraviolet and optical spectra of LMC 1988 #1 taken within the first two months of its outburst (when the atmosphere was still optically thick) with synthetic spectra computed using PHOENIX nova model atmospheres. The synthetic spectra reproduce most of the features seen in the spectra and provide V band magnitudes consistent with the observed light curve. The fits are improved by increasing the CNO abundances to 10 times the solar values. The bolometric luminosity of LMC 1988 #1 was approximately constant at $2 \times 10^{38}$ ergs s$^{-1}$ at a distance of 47.3 kpc for the first 2 months of the outburst until the formation of the dust shell.

Numerical Solution of the Expanding Stellar Atmosphere Problem
with E. Baron

In this paper we discuss numerical methods and algorithms for the solution of NLTE stellar atmosphere problems involving expanding atmospheres, e.g., found in novae, supernovae and stellar winds. We show how a scheme of nested iterations can be used to reduce the high dimension of the problem to a number of problems with smaller dimensions. As examples of these sub-problems, we discuss the numerical solution of the radiative transfer equation for relativistically expanding media with spherical symmetry, the solution of the multi-level non-LTE statistical equilibrium problem for extremely large model atoms, and our temperature correction procedure. Although modern iteration schemes are very efficient, parallel algorithms are essential in making large scale calculations feasible, therefore we discuss some parallelization schemes that we have developed.
A Non-LTE line-blanketed expanding atmosphere model for A-supergiant α Cygni with J. P. Aufdenberg, E. Baron

We present non-LTE metal line-blanketed expanding atmosphere models and synthetic spectra for comparison with the spectral energy distribution of A-supergiant ff Cyg from the UV to the radio. Our model treats the hydrostatic inner atmosphere and the extended expanding outer atmosphere as a unified structure and the radiative transfer is computed in the co-moving frame. By simultaneously fitting the UV, optical, IR and radio spectrophotometry we constrain $M$ Stability of the deep hydrostatic layers against outward acceleration demands that the gravitational potential at the photosphere be $\log g \approx 1.5$ The best fitting model angular diameter is in very good agreement with the most recent interferometric measurement. We find a good fit to the photospheric Balmer and Pfund lines. We fit the Mg II resonance lines and find a best fit terminal velocity of $v_\infty = 225\text{km/s}$. We present synthetic radio spectra from the partially ionized winds of A-supergiants over a range of mass-loss rates and we find the standard assumptions regarding the radio spectra of warm supergiants break down for A-supergiants.

non-LTE model atmosphere analysis of the early ultraviolet spectra of nova Andromedae 1986 with Greg J. Schwarz, S. Starrfield, E. Baron, France Allard, Steven N. Shore, and G. Sonneborn

We have analyzed the early optically thick ultraviolet spectra of Nova OS And 1986 using a grid of spherically symmetric, non-LTE, line-blanketed, expanding model atmospheres and synthetic spectra with the following set of parameters: $5,000 \leq T_{\text{model}} \leq 60,000\text{K}$, solar abundances, $\rho \propto r^{-3}$, $v_{\text{max}} = 2000\text{km/s}$, $L = 6 \times 10^4 \text{L}_\odot$, and a statistical or microturbulent velocity of $50\text{ km/s}^{-1}$. We used the synthetic spectra to estimate the model parameters corresponding to the observed IUE spectra. The fits to the observations were then iteratively improved by changing the parameters of the model atmospheres, in particular $T_{\text{model}}$ and the abundances, to arrive at the best fits to the optically thick pseudo-continuum and the features found in the IUE spectra.

The IUE spectra show two different optically thick subphases. The earliest spectra, taken a few days after maximum optical light, show a pseudo-continuum created by overlapping absorption lines. The later observations, taken approximately 3 weeks after maximum light, show the simultaneous presence of allowed, semi-forbidden, and forbidden lines in the observed spectra.

Analysis of these phases indicate that OS And 86 had solar metallicities except for Mg which showed evidence of being underabundant by as much as a factor of 10. We determine a distance of 5.1 kpc to OS And 86 and derive a peak bolometric luminosity of $\sim 5 \times 10^4 \text{L}_\odot$. The computed nova parameters provide insights into the physics of the early outburst and explain the spectra seen by IUE. Lastly, we find evidence in the later observations for large non-LTE effects of Fe II which, when included, lead to much better agreement with the observations.
List of Publications in refereed journals (2000–2001)
Peter H. Hauschildt


