Nova Framework: MESA and NuGrid Simulations of Classical Nova Outbursts and Nucleosynthesis

Classical novae are the results of surface thermonuclear explosions of hydrogen accreted by white dwarfs (WDs) from their low-mass binary companions. Chemical composition analysis of their ejecta shows that nova outbursts occur on both CO and more massive ONe WDs, and that there is mixing across the boundary between the accreted envelope and WD. We demonstrate that the state-of-the-art stellar evolution code MESA and post-processing nucleosynthesis tools of NuGrid can successfully be used for modeling of CO and ONe nova outbursts and nucleosynthesis (Denissenkov et al. 2013, arXiv:1303.6265v1 [astro-ph.SR]). The convective boundary mixing (CBM) in our 1D numerical simulations is implemented using a diffusion coefficient that is exponentially decreasing with a distance from the bottom of the convective envelope. We show that this prescription produces maximum temperature evolution profiles and nucleosynthesis yields in good agreement with those obtained using the widely-adopted 1D nova model in which the CBM is mimicked by assuming that the accreted envelope has been pre-mixed with WD's material. In our previous work (2013, ApJ, 762, 8), it has been found that ^{3}He is produced in solar-composition envelopes accreted with slow rates by very cold CO WDs, and that convection is triggered by the ^{3}He ignition in this case. In the present work, we confirm this result for ONe novae. Additionally, we find that the interplay between the ^{3}He production and destruction in the envelopes accreted with an intermediate rate by ONe WDs with relatively high central temperatures leads to the formation of a thick radiative buffer zone that separates the bottom of convective envelope from the WD surface.

We have combined the MESA and NuGrid codes into a new research Nova Framework that has already been verified and used to simulate more than 50 nova outbursts and their accompanying nucleosynthesis occurring on CO and ONe WDs.

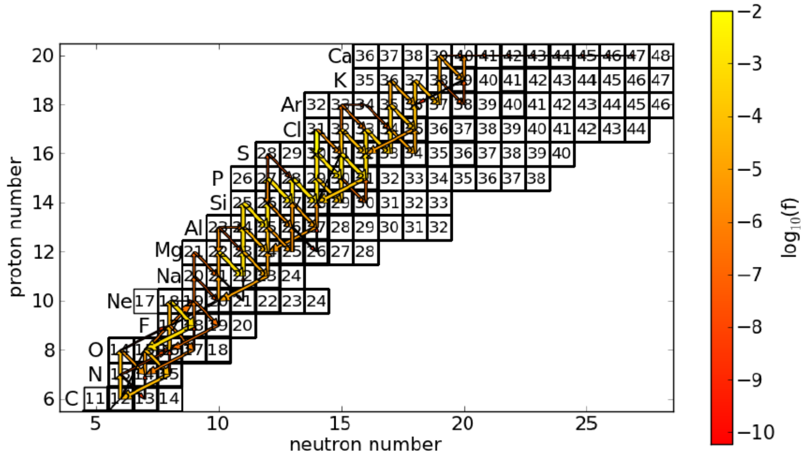

Figure 1: The net of 147 isotopes (H, He, Li, Be, and B isotopes are not plotted) used in our post-processing nova nucleosynthesis calculations. Reaction fluxes (arrows) correspond to our one-zone NuGrid simulation for the most extreme nova model with the peak temperature of 408 MK.

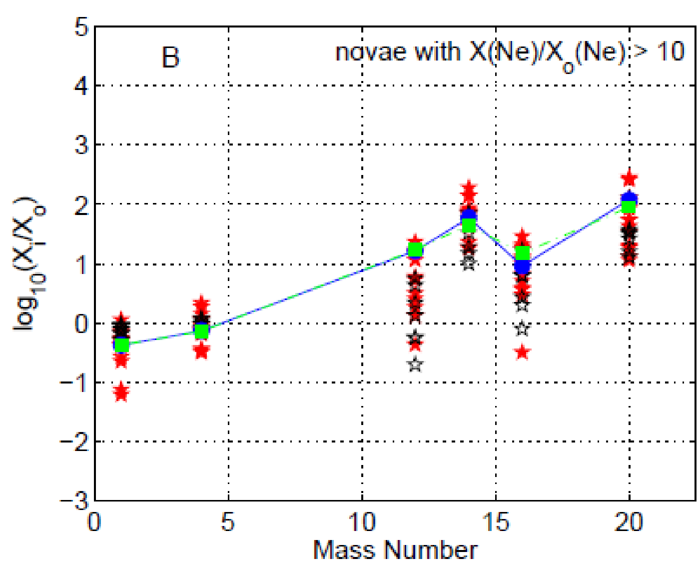

Figure 2: Comparison of the H, He, C, N, O, and Ne mass fractions in ONe novae from optical spectroscopy (red and black star symbols are data from Gehrz et al. 1998, PASP, 110, 3 and Downen et al. 2013, ApJ, 762, 105) with the ones predicted by our simulations (blue circles) and by models of Jose & Hernanz (1998, ApJ, 494, 680) (green squares).

Researchers: Pavel Denissenkov (UVic), Falk Herwig (UVic), Marco Pignatari (Basel), Jim Truran (Chicago)