Sensitivity study classical nova synthesis of ^{22}Na and ^{31}P

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Classical novae are explosions taking place on the surface of white dwarfs in binary systems where many nuclear reactions take place and consequently many elements are produced or destroyed, some of which might be ejected into the cosmos. Astronomers are particularly interested in studying the abundance of ^{22}Na, a radioactive isotope with a half-life of 2.6 years, because we can isotopically identify the source of the signal, which is something which cannot be done with elemental absorption lines. Sodium-22 has never been detected in the cosmos, while it has been produced synthetically. The long half-life of Sodium-22 increases its chances of living for long enough that it can be observed following ejection from the nova. Detection of ^{22}Na will give us information about the temperature and the mechanism of a Classical Nova and the reactions that take place during the Nova. The reactions that lead to the production and destruction of ^{22}Na are:

$^{21}\mathrm{Ne} + \mathrm{p} \rightarrow {}^{22}\mathrm{Na} + \boldsymbol{\gamma}$ (proton capture)

$^{22}\mathrm{Mg} \rightarrow {}^{22}\mathrm{Na} + e^{+} + \boldsymbol{\nu}_e + \boldsymbol{\gamma}$ (beta plus decay)

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We use sensitivity studies to determine the impact of reaction rates on the overall evolution and properties of the astrophysical system, to find the key reactions in nucleosynthesis reaction networks and production of specific isotopes, to determine the abundance of isotopes and elements produced in the nucleosynthesis process, and to help determine the mutual impact of the nuclear rates uncertainties and different astrophysical parameters on each other in different stellar environments.

We use MESA (Modules for Experiment in Stellar Astrophysics), which is an open source one-dimensional general module to simulate the evolution and properties of stars.

By modifying the control parameters and inputs, one can simulate different stellar evolution scenarios. In our case, we have simulated the evolution of a carbon-oxygen (CO) white dwarf in a binary system with a companion star and the occurrence of the classical novae

In Fig. 1, the abundance of ^{22}Na is plotted against time, for different rates of ^{22}Na(p,γ)^{23}Mg reaction. The origin of time is chosen to be the peak of the burst. The peak of the burst is defined as the maximum of T_{max}. The red cross is the maximum of ^{22}Na abundance for each rate. The black diamond is the abundance at the peak of the burst. The 5 green crosses are respectively showing the abundance at 90, 120, 180, 240, 300 minutes after the peak of the burst. As can be seen the abundances of Na decrease by increasing the rate of the reaction, indicating more Na is destroyed and turned into Mg, and vice versa by decreasing the reaction rate.

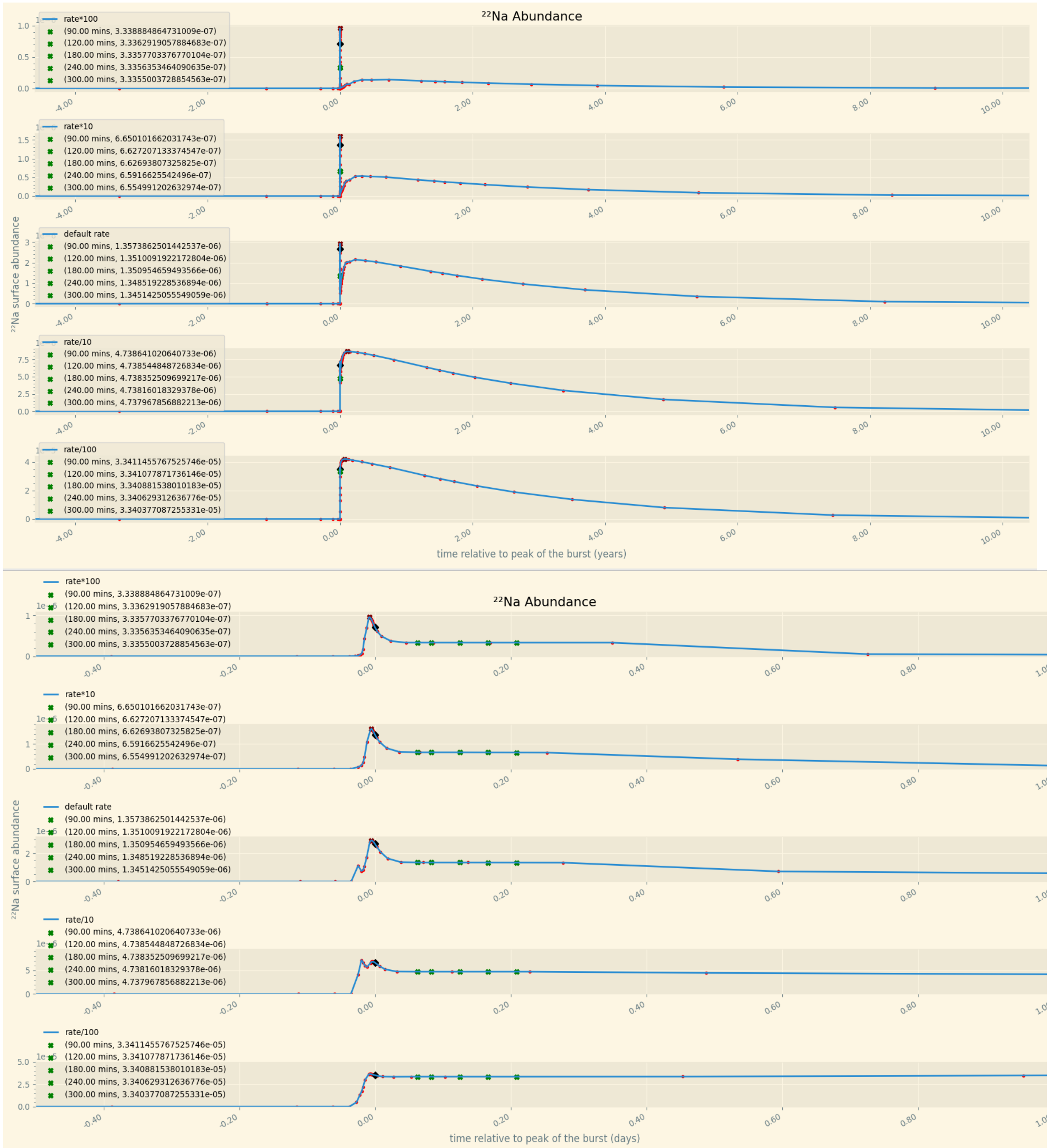

FIG. 1. ^{22}Na+^{23}Na abundances as function of time for different ^{22}Na(p, γ)^{23}Mg reaction rates.

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Once the impact of different nuclear reactions on the ^{22}Na abundance have been determined, we plan to extend our studies to the production of phosphorus (^{31}P). According to a recent paper by Bekki and Takuji 2024, the [P/Fe] changes over time are not well explained by core collapse supernovae models while oxygen-neon (ONe) novae on the surface of a white dwarf with a metallicity-dependence rate and a mass greater than 1.25 $M_\odot$ is demonstrated to be a good candidate to explain and predict the variation in ^{31}P abundances over time.