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Rapidly-Accreting White Dwarfs and the i-Process in a Galactic Chemical Evolution Context

A rapidly-accreting white dwarf (RAWD) is a white dwarf that accretes matter from a companion star (Fig.1), rapidly enough to steadily burn on its surface the accreted hydrogen into helium. Once a RAWD reaches a critical mass, the accumulated shell of helium undergoes a thermal flash that triggers convection. This convective motion ingests protons into the helium shell, which are thereafter captured by ^{12}C to form ^{13}N. While being transported by convection to the bottom of the helium shell, ^{13}N decays into ^{13}C. Neutrons are then released via the reaction ^{13}C(alpha,n)^{16}O. The number density of neutrons in this convective-reactive process can reach a value of about 10^{15} neutrons per cm^3, intermediate between those characteristic of the slow (s) and rapid (r) neutron-capture processes, thus called the intermediate (i-) process.

Figure 1. Artist illustration of a white dwarf (right object) accreting gas from a companion star (left object). ©ESA and Justyn Maund (Queens University Belfast).

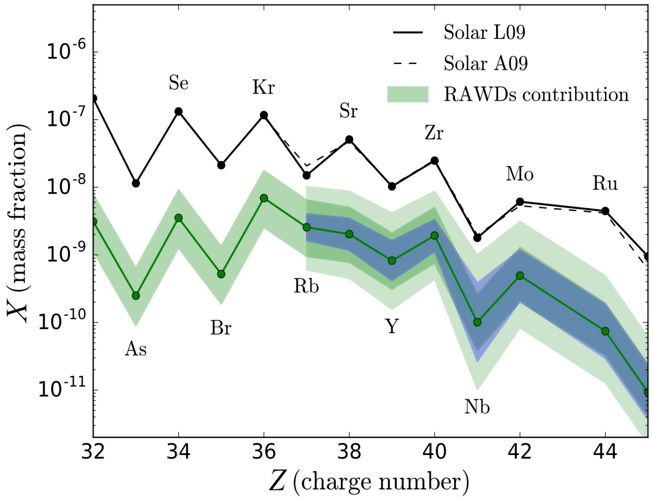

Figure 2. Abundances (y axis) of first-peak neutron-capture elements (x axis) observed in the Sun (black lines). The green line shows the predicted contribution of RAWDs using our galactic chemical evolution model. Dark-green and blue shaded areas highlight uncertainties from galaxy evolution modeling and from cross sections involved in nuclear reaction rates [4], respectively. The lighter-green shaded area shows the combined uncertainties.

In a recent study [1], we introduced the i-process yields calculated by P. Denissenkov [2] into our galaxy model [3] in order to quantify the contribution of RAWDs (via the i-process) on the chemical evolution of neutron-capture elements in the Milky Way. We found that RAWDs could contribute to a non-negligible fraction of first-peak neutron-capture elements observed in the Sun, such as Rb, Sr, Y, and Zr (Fig.2). We also demonstrated that the i process can complement the s process in recovering the isotopic composition of the Sun (e.g., ^{96}Zr, ^{95}Mo, and ^{97}Mo). In addition, this study clearly highlighted that nuclear physics uncertainties [4] have a major impact on the predictive power of chemical evolution models, a reminder of the necessity of inter-disciplinary collaborations.

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[1] B. Côté et al., 2018, ApJ, 854, 105
[2] P. Denissenkov, et al., 2017, ApJ, 834, L10
[3] NuGrid Python Chemical Evolution Environment (http://nugrid.github.io/NuPyCEE/)
[4] P. Denissenkov, et al., 2018, JphG, 45e5203