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Roles of nuclear weak rates on the evolution of degenerate cores in stars

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Electron-capture and β-decay rates in nuclei at stellar environments evaluated with new shell-model Hamiltonians have been applied to cooling processes and nucleosynthesis in electron-degenerate cores in stars.
Nuclear Urca processes in electron-degenerate O-Ne-Mg cores of stars with initial masses of 8-10 $M_\odot$ have been studied using the weak rates for sd-shell nuclei obtained for the USDB Hamiltonian, and the processes for nuclear pairs with A=23 and 25 are found to be important for the cooling of the cores and determination of the final fate of the stars [1].
Important roles of the nuclear Urca processes have been pointed out also in C-O and hybrid C-O-Ne white dwarfs (WD) [2,3]. The nuclear weak rates obtained in a large region of pf-shell nuclei by GXPF1J [4] have been applied to study nucleosynthesis in Type-Ia supernova explosions (SNe), which result from accreting C-O WD in close binaries. Over-production of neutron-rich isotopes in the iron group elements compared to the solar abundance noticed for the Fuller-Fowler-Newman rates has been considerably reduced [5].

We extend our study of applications of updated nuclear weak rates to cooling processes and evolution of degenerate cores in stars in the region outside one-major sd- and pf-shells. The weak rates for nuclear pairs important for Urca processes in neutron star crusts [6] are studied.
In particular, weak rates of nuclei in the island of inversion such as ^{31}Mg are evaluated based on microscopic interactions obtained by extended Kuo-Krenciglowa (EKK) method [7].
The method can explain well the structure of neutron-rich Mg isotopes.
Spectra of ^{31}Mg, in particular, are successfully reproduced by the EKK method in contrast to other approaches.

Fe-core-collapse SNe are sensitive to the e-capture rates for extremely neutron-rich isotopes near ^{78}Ni [8] as well as iron group nuclei. Electron-capture rates in ^{78}Ni are evaluated with extension of the configuration space outside the pf-shell [9], and compared with RPA calculations and Sullivan's approximate formula [8]. In p-shell region, an accurate shell-model evaluation is carried out for e-capture rates on ^{13}N, which is important during carbon simmering stage of C-O WD prior to the onset of thermonuclear explosions [3].
Nuclear weak transition rates, thus, play important roles on the final evolution of degenerate cores in stars. Accurate evaluation of the nuclear weak rates is essential for the studies of astrophysical processes sensitive to the rates.
\bigskip
{\small

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