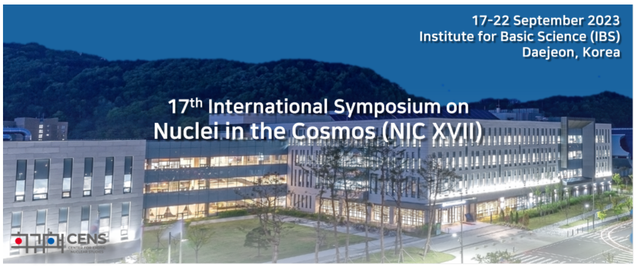

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High-precision nuclear chronometer for the cosmos

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Nuclear chronometer provides an independent dating technique for the cosmos by predicting the ages of the oldest stars. Similar to geochronology, the ages are determined by comparing the present and initial abundances of long-lived radioactive nuclides. In nuclear cosmochronology, the present abundances can be obtained from the astrophysical observations whereas the initial abundances have to be determined by simulations of rapid neutron capture (r-process) nucleosynthesis. However, the previous Th/X, U/X, and Th/U chronometers suffer from the uncertainties of the r-process simulations, which leads to a poor identification on the cosmic age. Here we show that the precision of the nuclear chronometer can be significantly improved by synchronizing the three different types of nuclear chronometers, as it imposes stringent constraints on the astrophysical conditions in the r-process simulation. The new chronometer (Th-U-X) reduces the uncertainties of the predicted ages from the astrophysical conditions, more than ±2 billion years for the Th/U chronometer, to within 0.3 billion years. By the Th-U-X chronometer, ages of the six metal-poor stars with observed uranium abundances are estimated to be varying from 11 to 17 billion years, two of which disfavor the young cosmic age of 11.4 billion years by a recent measurement of Hubble constant from angular diameter distances to two gravitational lenses. Our results demonstrate that the Th-U-X chronometer provides a high-precision dating technique for the cosmic age. For perspective, the Th-U-X chronometer can serve as a standard technique in nuclear cosmochronology. It will be even more appealing in case that the r-process site is identified whereas the corresponding detailed conditions remain unknown, as it can filter out unreasonable conditions by synchronizing nuclear chronometers.

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