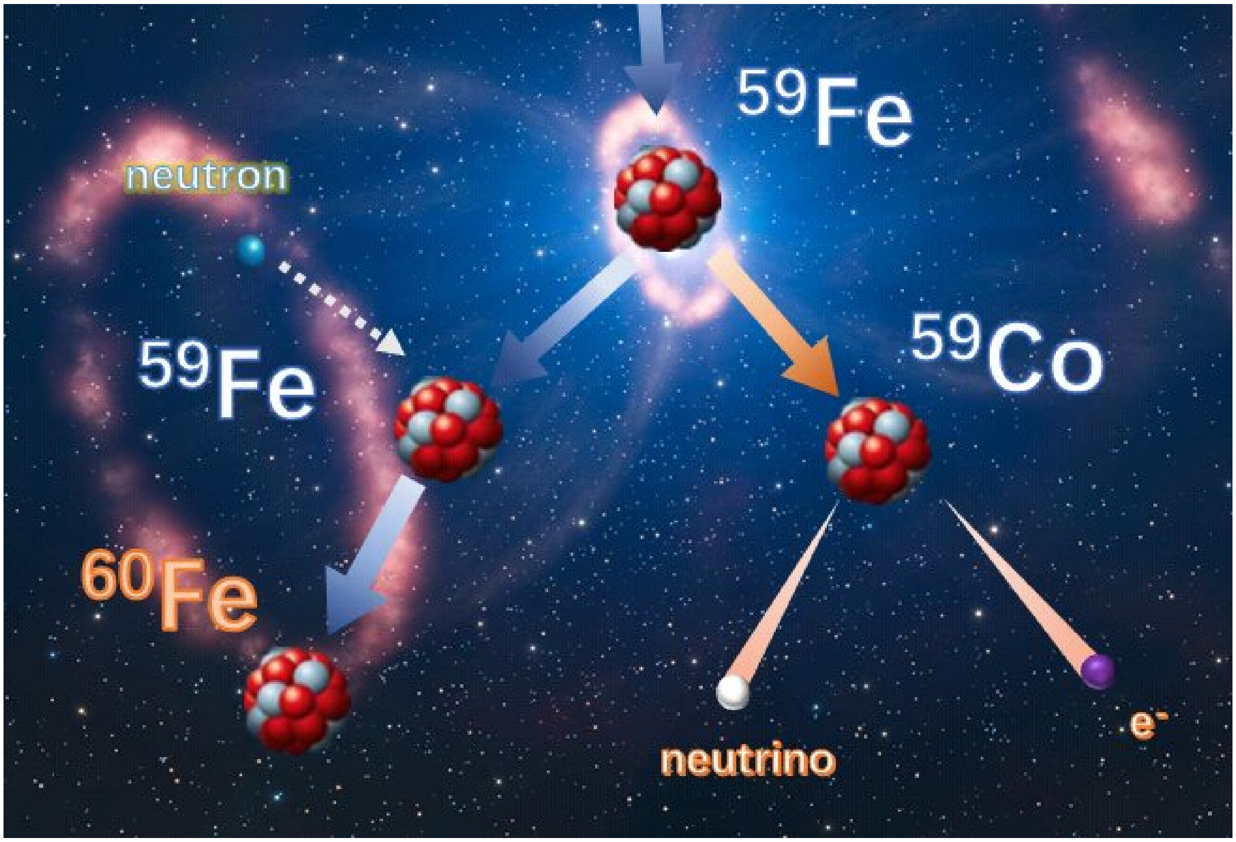
# Study sheds light on stellar origin of iron nuclide

April 16 2021



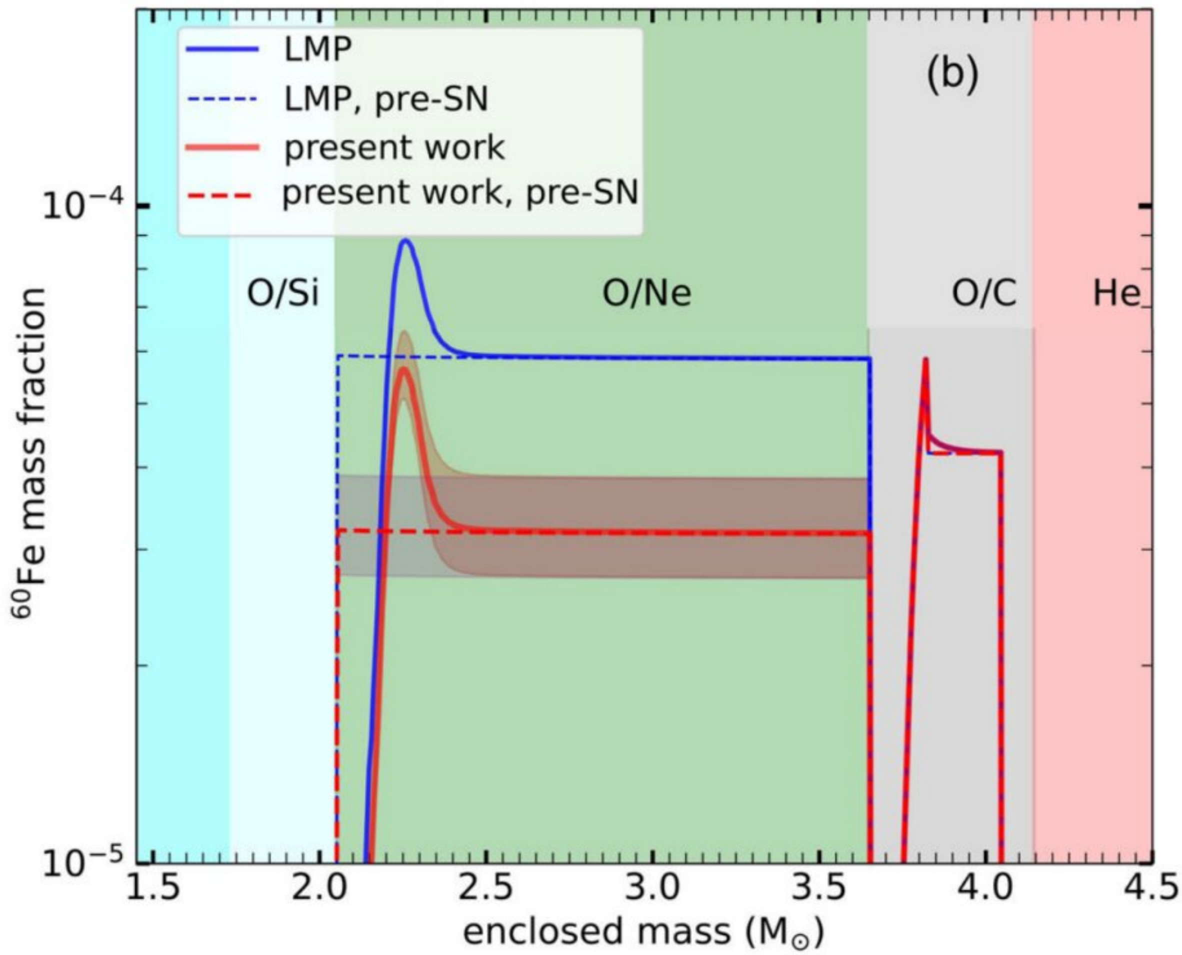

$^{60}Fe$ nucleosynthesis in massive stars. Credit: LI Yutian

Researchers from the Institute of Modern Physics (IMP) of the Chinese Academy of Sciences and their collaborators have recently made great progress in the study of the stellar beta-decay rate of $^{59}Fe$, which constitutes an important step towards understanding $^{60}Fe$ nucleosynthesis in massive stars. The results were published in *Physical Review Letters* on April 12.

Radioactive nuclide $^{60}Fe$ plays an essential role in nuclear astrophysical studies. It is synthesized in massive stars by successive neutron captures on a stable nucleus of $^{58}Fe$ and, during the late stages of stellar evolution, ejected into space via a core-collapse supernova.

The characteristic gamma lines associated with the decay of $^{60}Fe$ have been detected by space gamma-ray detectors. By comparing the $^{60}Fe$ gamma-ray flux to that from $^{26}Al$, which shares a similar origin as $^{60}Fe$, researchers should be able to obtain important information on nucleosynthesis and stellar models. However, the observed gamma-ray flux ratio $^{26}Al/^{60}Fe$ does not match theoretical predictions due to uncertainties in both stellar models and nuclear data inputs.

The stellar beta-decay rate of $^{59}Fe$ is among the greatest uncertainties in nuclear data inputs. During the nucleosynthesis of $^{60}Fe$ in massive stars, $^{59}Fe$ can either capture a neutron to produce $^{60}Fe$ or beta decay to $^{59}Co$. Therefore, the stellar beta-decay rate of $^{59}Fe$ is critical to the yield of $^{60}Fe$.




$^{60}Fe$ yield in 18 solar mass star. Blue lines (LMP) are calculations based on previous decay rate, red lines (present work) are those based on the new measurement. Credit: *Physical Review Letters*

Although the decay rate of $^{59}Fe$ has been accurately measured in laboratories, its decay rate may be significantly enhanced in stellar environments due to contributions from its excited states. However, direct measurement of the beta-decay rate from excited states is very challenging since one has to create a high-temperature environment as in stars to keep the $^{59}Fe$ nuclei in their excited states.

To address this problem, researchers at IMP proposed a new method for measuring the stellar beta-decay rate of $^{59}$Fe. "The nuclear charge-exchange reaction is an indirect measurement alternative, which provides key nuclear structure information that can determine those decay rates." said Gao Bingshui, a researcher at IMP.

The researchers carried out their experiment at the Coupled Cyclotron Facility at Michigan State University. In the experiment, a secondary triton beam produced by the cyclotrons was used to bombard a $^{59}$Co target. Then the reaction products, $^{3}$He particles and gamma rays, were detected by the S800 spectrometer and GRETINA gamma-ray detection array. Using this information, the beta-decay rates from the $^{59}$Fe excited states were determined. This measurement thus eliminated one of the major nuclear uncertainties in predicting the yield of $^{60}$Fe.

By comparing stellar model calculations using the new decay rate data with previous calculations, the researchers found that, for an 18 solar mass star, the yield of $^{60}$Fe is 40% less when using the new data. The result points to a reduced tension in the discrepancy in $^{26}$Al/$^{60}$Fe ratios between theoretical predictions and observations.

"It is an important step towards understanding $^{60}$Fe nucleosynthesis in massive stars and it will provide a more solid basis for future astrophysical simulations," said Li Kuoang, the collaborator of Gao.

**More information:** B. Gao et al, New Fe59 Stellar Decay Rate with Implications for the Fe60 Radioactivity in Massive Stars, *Physical Review Letters* (2021). DOI: 10.1103/PhysRevLett.126.152701

Provided by Chinese Academy of Sciences

Citation: Study sheds light on stellar origin of iron nuclide (2021, April 16) retrieved 27 April 2024 from https://phys.org/news/2021-04-stellar-iron-nuclide.html