Nuclear Cosmology & Astrophysics
Nuclear radiation detectors are used in explorations of the sun and its planets. Space vehicles use them to detect and identify directly emitted or back-scattered radiation. Surface materials on Mars have been analyzed using activation methods using radioactive sources.
Activation Radiation from Planetary Surface

Group project: N* Detector for Application in Nuclear Forensics
Nucleosynthesis

\[ r-p \text{ process (rapid-proton capture) produces heavy elements.} \]

\[ r \text{ process (rapid-neutron capture)} \]

Strong T dependence

Details of nuclear structure and stability and the conditions at formation (star, Big Bang) account for the natural abundance of elements.

Much of the information needed is not yet known

\[ \rightarrow \text{Task of future experiments.} \]
Abundance of Solar Elements

Too many heavy elements for production in solar burning processes.

Temperature is too low in solar interior ($T_g = 0.015 \text{ K, } \rho = 158 \text{ g/cm}^3$).

Sun is result of evolution through several stellar life cycles (accretion of interstellar dust, ignition, burning, collapse and explosion).

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Studying Nuclear Reactions in Supernova Explosions

Time-of-flight spectrum of neutrinos, measured relative to $\gamma$-rays.

0.85 MeV and 1.24 MeV $\gamma$-rays from $^{56}$Co synthesized in the SN.
Supernova 1994D in Galaxy NGC 4526 (108 M ly). It is brighter than the galaxy. (Hubble Space Telescope, NASA)
Supernova: Collapse and Explosion of a Star

(Simulation: NASA)
Neutron star and companion in a binary system. Accretion disk is created from matter pulled out of the companion.

Matter impinging on the neutron star’s surface creates nuclear reactions. sp and rp processes proceed rapidly along drip lines and drive X-ray bursts that can be observed on earth.
Structure of a Neutron Star

Inner boundary of inner crust:
Transition to uniform “neutron matter.” Cylindrical and plate-like type of nuclear “pasta.”

Outer core: Composed of neutron-rich nuclear matter. Governs stellar radii, and moments of inertia.

Inner core: Composition is unknown. Could be nuclear, quark or strange matter. Governs maximum stellar mass, and cooling of proto-neutron star.
rp Reactions flow during X-Ray Burst

rp reaction flow (red line) during X-ray burst.

The series ends at the Sn-Sb-Te cycle.

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