



Editorial: Nuclear Reactions of Astrophysical Interest

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Editorial on the Research Topic

Nuclear Reactions of Astrophysical Interest

Several astrophysics theoretical predictions are strictly dependent on the availability of theoretical/experimental information about fusion cross sections at the energies of astrophysical interest; suffice to say that the development of stellar astrophysics during the first decades of the 20th century is mainly due to the insight that stars are powered by thermonuclear reactions.

The most of the elements present in the Universe are formed through nuclear fusions among charged nuclei and nuclear/neutron captures on nuclides in stellar cores; the fusion energies are well below the Coulomb barrier for reactions among charged particles. Moreover some reactions involve weak interactions with a consequent strong reduction of the reaction rate. Thus the measurement of cross sections at astrophysical interest is a challenge which requires the installation of the detectors underground to reduce the background due to cosmic rays and the development of "ad hoc" detection methods. Moreover suitable formalism for nuclear astrophysics calculations must be developed.

Thus nuclear astrophysics is an inter-disciplinary field which connects astrophysics (mainly stellar physics and cosmological nucleosynthesis) to experimental techniques of low energy cross section measurements and nuclear physics theory. In the last 2 decades the measurements/calculations of many cross sections of astrophysical interest have been greatly improved, however in several cases the still present uncertainties affect in a not negligible (or in some cases in a severe) way, the predictions for stellar characteristics and element nucleosynthesis.

This Research Topic summarizes the present situation for research fields in which the synergy between nuclear physics and astrophysics is especially evident. In details it will cover the fundamental topics listed below:

- primordial nucleosynthesis: the formation of elements in the early Universe is explored in terms of its dependence on nuclear inputs. In particular the primordial lithium problem is addressed in terms of recent observations as well as an up-to-date compilation of nuclear reaction rates of interest arising from direct and indirect measurements;
- solar and stellar models: stellar models are investigated with a balanced focus on both massive and smaller mass stars. Their importance for nucleosynthesis is examined in details with big attention paid to the role of nuclear inputs in different phases of stellar evolution. Other important current issues are also addressed such as transport mechanisms, opacities, surface abundance patterns and measurements, etc. The role of stars in advanced evolutionary phases (Asymptotic Giant Branch) as source of presolar oxyde grains is discussed also in dependence

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of relevant nuclear reaction rates. Solar models and solar neutrino production are also reviewed with special attention to recent developments;

- the importance of light elements in nuclear astrophysics: light elements (Li, Be and B) play an important role in various stellar physics and cosmological problems. In this research topic the different aspects of the issue will be addressed from their cosmological importance to the role of Li, Be and B surface abundances in stars as possible trackers of internal mixings and other stellar processes. Particular attention will be devoted to the dependence of light element abundances on nuclear reaction rate measurements. The observational techniques and the results for surface light elements abundances in stars of different types and belonging to different Galactic populations will be also described.
- neutron mergers in binary systems emerged recently as a fundamental mechanism for nucleosynthesis of heavy elements in the Universe; in 2017 one of such systems was discovered for the first time by the LIGO-Virgo collaboration as source of gravitational waves as well as the production place for r-process nucleosynthesis;
- direct and indirect measurements of nuclear cross sections at astrophysical energies are fundamental to model stellar structure and evolution since nuclear reaction rates determine the nucleosynthesis processes as well as the energy production in stars. Moreover also cosmological nucleosynthesis is affected by nuclear cross section values. The measurement of neutron or charged particle induced reactions at astrophysical energies is a very challenging task. To this purpose direct measurements must be performed underground (e.g., the LUNA facilities) and powerful indirect methods (e.g., Trojan Horse Method (THM), Asymptotic normalization Coefficient (ANC), Transfer reactions) are used as complementary tools to determine the reaction rates at energies far below the Coulomb barrier (in the case of charged particles interactions);
- theoretical methods for nuclear astrophysics provide the framework that allowed indirect methods to be developed and applied in experimental nuclear astrophysics. They are also a precious tool in the cases in which extrapolations are mandatory. A dedicated review will offer a bird-eye view of their achievements and applications in nuclear astrophysics.

The aim of the Research Topic is many-fold: 1) to made available to people who adopt theoretical stellar and/or nucleosynthesis models an evaluations of the still present theoretical uncertainties due to errors in nuclear cross sections. These uncertainties will be also compared to the ones

due to the indetermination on other input quantities for models. 2) To summarize the “status of art” of the experimental measurements for nuclear cross sections relevant for stellar physics and primordial nucleosynthesis. 3) to focus on the synergic efforts driven by direct and indirect methods in nuclear astrophysics in order to measure cross sections of astrophysical interest at the Gamow energies. This is of great importance for reaction induced on stable nuclei (like the ones which are dealt with in this work) and is the only way for understanding explosive nucleosynthesis (mainly driven by reactions on unstable nuclei interacting with charged particles or neutrons). 4) To offer to astrophysicists a comprehensive view of experimental results and a description of recent outcomes for nuclear astrophysics open problems and vice-versa to offer to nuclear physicists a clear view of the demands of nuclear inputs for our understanding of the Universe.

We believe that the synergic efforts of the two communities as well as the building up of a *common foundation* for new generations of investigators will lead to a stronger nuclear astrophysical community which may be one of the keys to a better understanding of the physical processes taking place in the Universe.

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SDI, LL and RP conceived the research topic together and wrote the present editorial synergically.

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