



SCHOOL OF ENGINEERING AND TECHNOLOGY

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Natural Gamma Transmutation Studies

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Gamma rays are photons more energetic than X-rays, and are found everywhere in space. Most are isotropic and do not have a well-understood origin. This pervasive flux is called the “gamma fog” and has a broad spectrum of energies. This natural bounty of gamma rays is an intriguing alternative to artificial gamma sources studied on earth (from particle beam accelerators and nuclear isotopes).

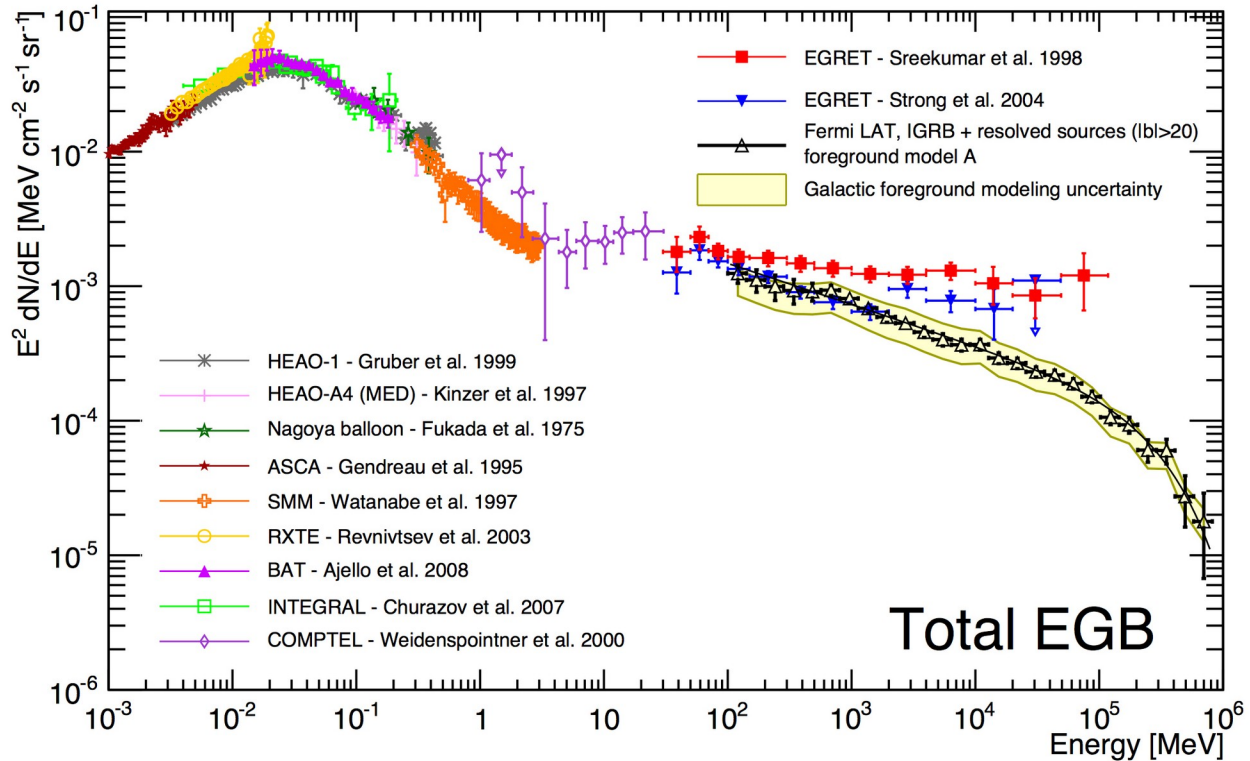


Figure 1. Gamma fog energy spectrum of Extra-Galactic Background, from multiple sources.

The element beryllium (Be) emits neutrons when exposed to gamma rays. Thus, a simple source of neutrons in space can be produced simply by exposing Be to deep space. Note that solar neutrons hardly ever reach Earth, as their half-life is just 15 minutes, so only a few relativistic particles reach cislunar space.

Graphite does not absorb neutrons, but scatters them such that their velocity soon comes into thermal equilibrium with the carbon matrix. These slow, or “thermal” neutrons, can be used for nuclear transmutation studies in space. The apparatus can be incredibly simple, and because both Be and graphite have low density, launch mass can be small.

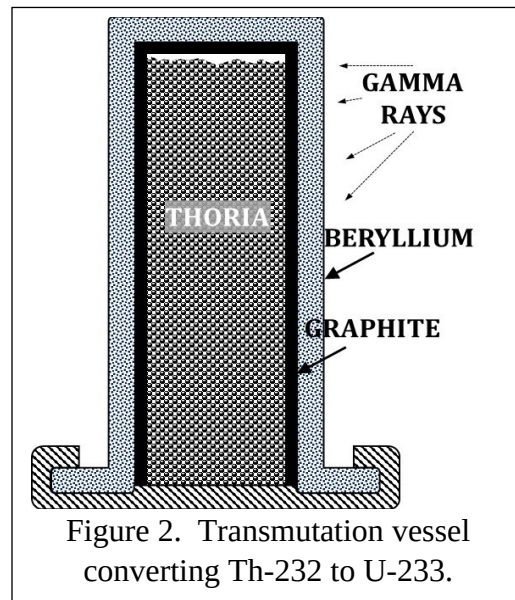
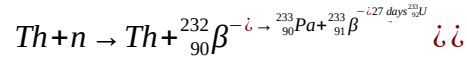


Figure 2. Transmutation vessel converting Th-232 to U-233.

Thorium has been found on the lunar surface. It is most abundant on the Near Side north of the equator. Some craters, where impact excavation has occurred, may have Th concentrations twice that found on earth, circa 20 parts per million. When Th absorbs a thermal neutron it transmutes into protactinium (Pa) and then spontaneously changes to a very attractive isotope of uranium. U-233 is fissile, and, when used in a nuclear pile, produces short-lived byproducts which need warning signs (on the Moon) to last for less than a century.



These factors make possible the scientific study of natural transmutation of Th via a Be/C vessel. An additional study with the same Be apparatus is to first remove the graphite, and evaluate gamma-generated fast neutron spectra for initiating a future fission reactor. A very important feature in this experimental design is that absolutely zero radioactive materials are launched from earth. This is of enormous significance, as any launch of a nuclear reactor (military secrets aside) is likely to meet significant vocal and legal opposition from concerned citizens around the world.

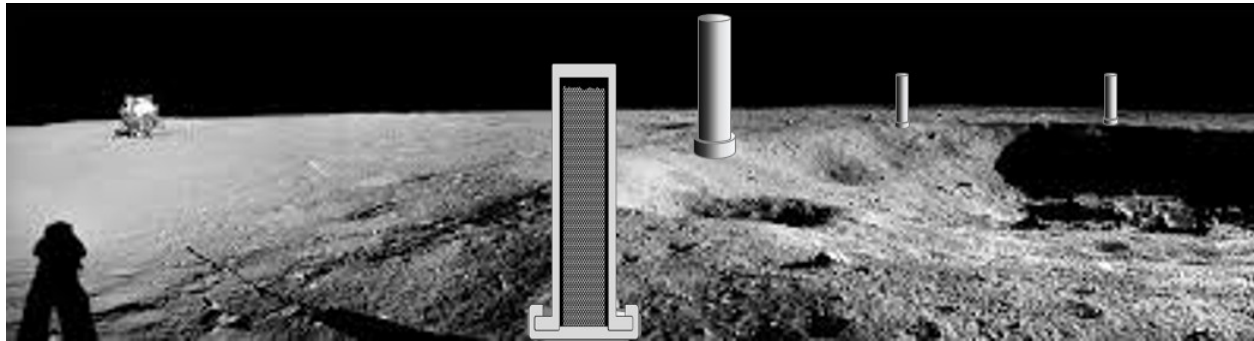


Figure 3. Placement of transmutation vessels along crater rim for gamma ray exposure, foremost cut-away.

These scientific studies have merit in addressing fundamental questions of physics and radiochemistry. There are also considerable practical applications. A NASA facility which includes an atomic pile based on U-233 could be harvested for thermal power to run a Brayton or Stirling cycle heat engine turning a dynamo to produce electricity. Even a crude first reactor could power and heat a long-duration habitat, and even run additional experiments. Nearly every science mission can benefit from more power, making this concept fundamental to many others.

Once NASA has conducted the scientific studies and proof-of-concept for transmutation of lunar thorium into fissile uranium, this will establish the basis for commercial entities to establish ultra-safe nuclear reactors around the Moon. A megawatt-class nuclear reactor in the proximity of a permanently-shadowed region inside a polar crater could provide the heat to extract water from ancient regolith. The electrical output can split this water into hydrogen and oxygen. Such a commercial entity can sell life support and rocket fuel to further missions. This concept thus has tremendous leverage to fulfil the goals of Space Directive-1 (2017) to: “enable human expansion across the solar system and to bring back to Earth new knowledge and opportunities.”

Sources

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