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Commercializing a Next-Generation Source of Safe Nuclear Energy

Low Energy Nuclear Reactions (LENRs)

Weak interaction LENR transmutation reactions on Earth versus nucleosynthesis in stars

Brief Semi-Technical Overview

"Energy, broadly defined, has become the most important geostrategic and geoeconomic challenge of our time."

Thomas Friedman
New York Times, April 28, 2006

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Fusion and fission are not predominant in LENR systems

Fundamental concepts of condensed matter weak interactions in Widom-Larsen theory of LENRs are illustrated below:

1. **E-M radiation on metallic hydride surface increases mass of surface plasmon electrons**
2. **Heavy-mass surface plasmon polariton electrons ($\tilde{e}^-$) react directly with surface protons (p^+) or deuterons (d^+) to produce ultra low momentum (ULM) neutrons (n_{ulm} or $2n_{ulm}$, respectively) and an electron neutrino (ν_e)**
3. **Ultra low momentum neutrons (n_{ulm}) are captured by nearby atomic nuclei (Z, A) representing some element with charge (Z) and atomic mass (A). ULM neutron absorption produces a heavier-mass isotope ($Z, A+1$) via transmutation. This new isotope ($Z, A+1$) may itself be stable or unstable**
4. **Unstable isotopes beta decay, producing: transmuted new element with increased charge ($Z+1$), ~ same mass ($A+1$) as "parent" nucleus; β particle (e^-); and antineutrino ($\bar{\nu}_e$)**

No strong interaction fusion or heavy element fission taking place below

1. $(\text{radiation}) + e^- \rightarrow \tilde{e}^-$

2. $\tilde{e}^- + p^+ \rightarrow n_{ulm} + \nu_e$

   $\tilde{e}^- + d^+ \rightarrow 2n_{ulm} + \nu_e$

3. $n_{ulm} + (Z, A) \rightarrow (Z, A+1)$

4. $(Z, A+1) \rightarrow (Z+1, A+1) + e^- + \bar{\nu}_e$

Unstable or Stable

Unstable Isotope

New element – stable or unstable

'Green' weak interaction β⁻ decays (above), alpha decays (not shown), and gamma-shielded neutron captures produce most of the energy

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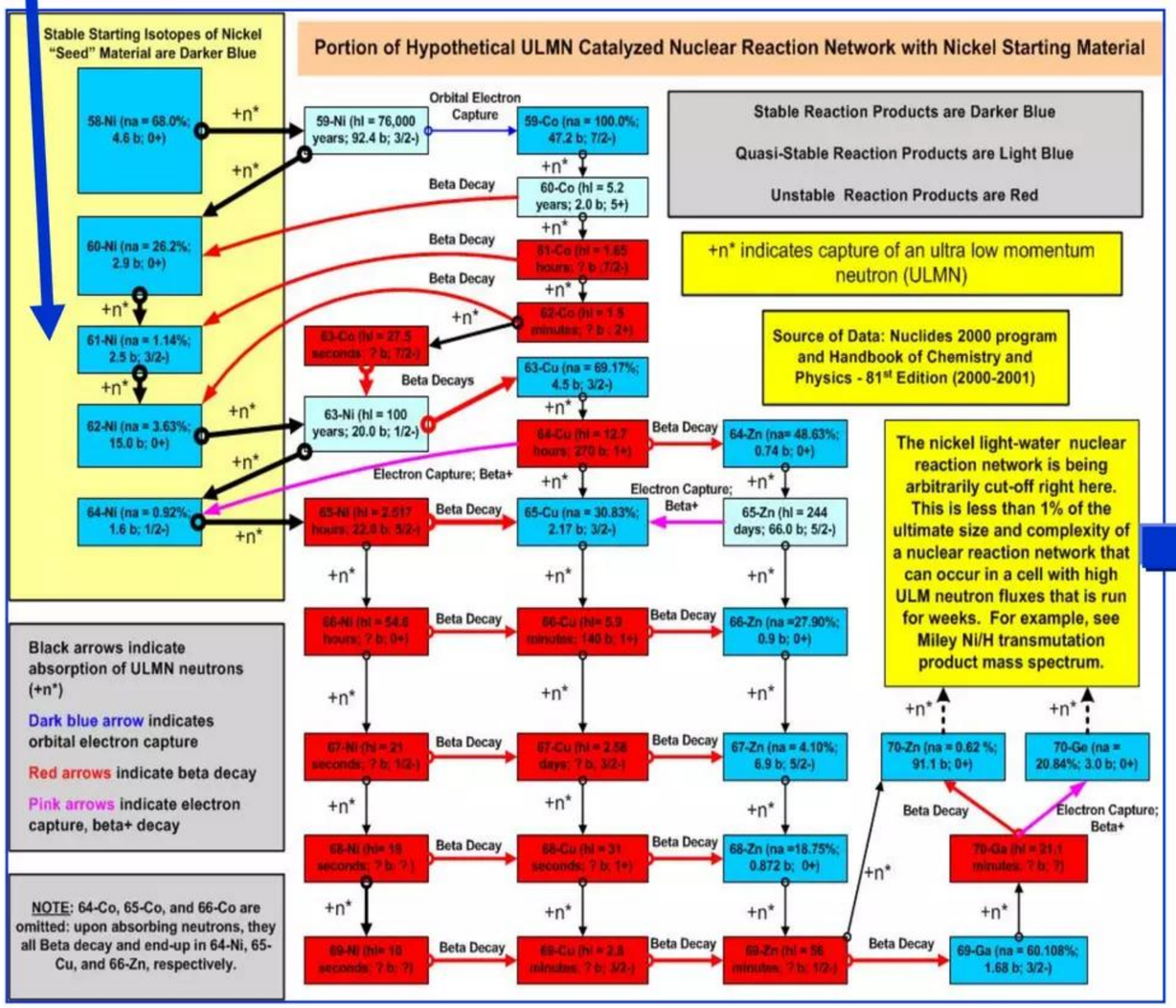
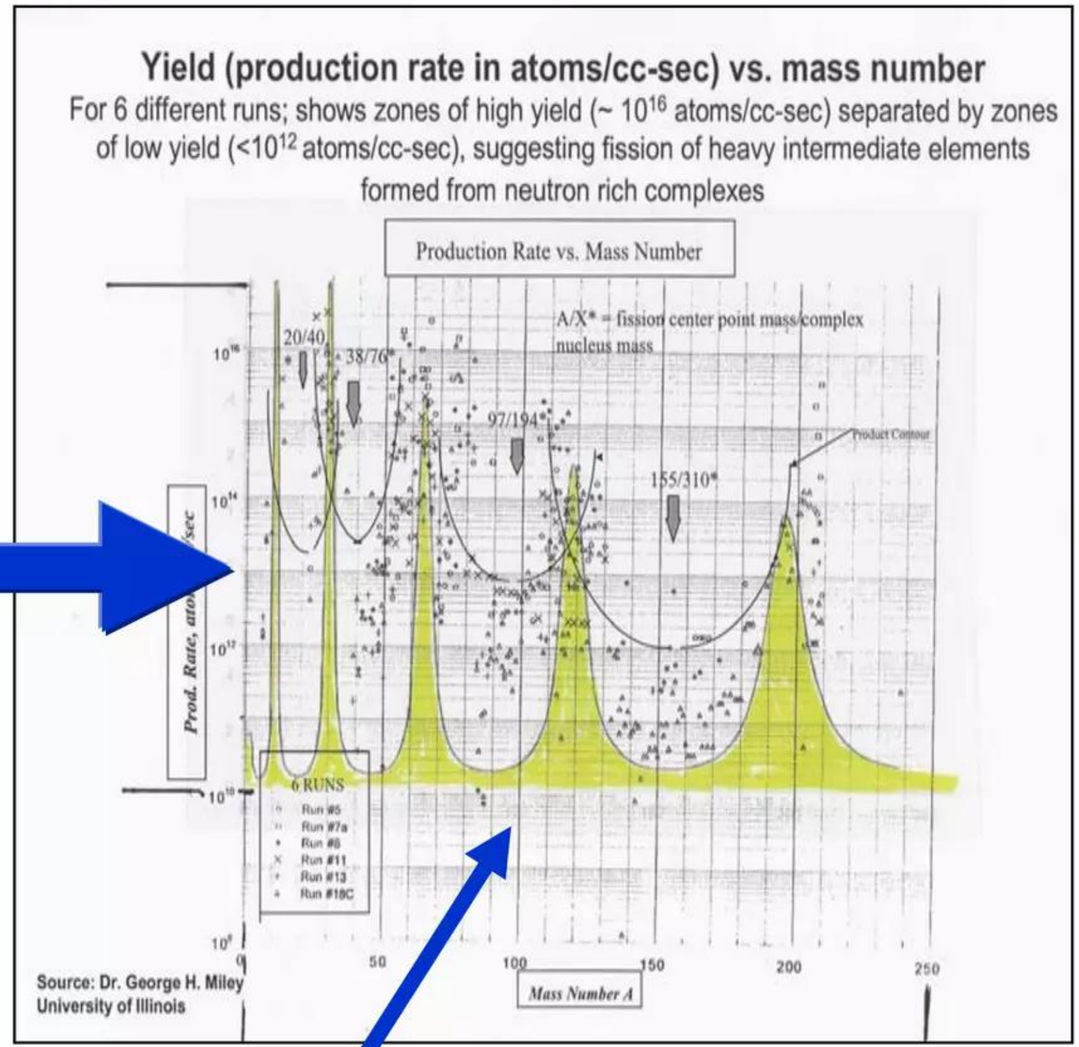
Neutron-capture transmutations on earth via LENRs

Miley et al. began with an ordinary Nickel cathode - two weeks later, ended-up with experimentally observed LENR transmutation product spectrum that looked like it had been created in a star

Start – Nickel (Ni) cathode placed in current-driven electrolytic chemical cell



Finish - Mass spectrum of LENR transmutation products in cathode



See: "Nuclear Abundances in Metallic Hydride Electrodes of Electrolytic Chemical Cells" arXiv:cond-mat/0602472 (Feb 2006) Widom and Larsen

With no fitting, simple two-parameter 'optical' model of ULM neutron absorption based on W-L theory of LENRs predicts product isotopic abundance peaks shown in yellow above

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Transmutations in nature: element nucleosynthesis in stars

- Except for Big Bang hydrogen/deuterium and helium, astrophysicists believe that most elements in the Universe lighter than Iron (Fe) were created by charged-particle fusion reactions inside stars

- Elements heavier than Fe thought to be created via neutron capture (absorption) nucleosynthesis reactions in stars. Two types of such neutron capture processes thought to occur in hot stellar plasmas:
  - s-process (slow) occurs in stars, e.g., red giants; neutron flux $10^5 - 10^{11}$ cm^2/sec
  - r-process (rapid) occurs in supernova explosions; neutron flux > 10^{22} cm^2/sec

- Heavier elements (A > Fe) are formed in successive cycles of neutron creation, neutron absorption, neutrino production, beta decays of unstable neutron-rich isotopes, and stable element production

According to Widom-Larsen, similar to condensed matter LENR systems where neutron flux can be $10^9 - 10^{16}$ cm^2/sec

Difference is that neutrons in LENR systems can be ultra low momentum; vastly larger absorption cross-sections

Also unlike stars, little gamma photodissociation; sometimes net rate of nucleosynthesis can be higher in LENR systems than in some stellar environments

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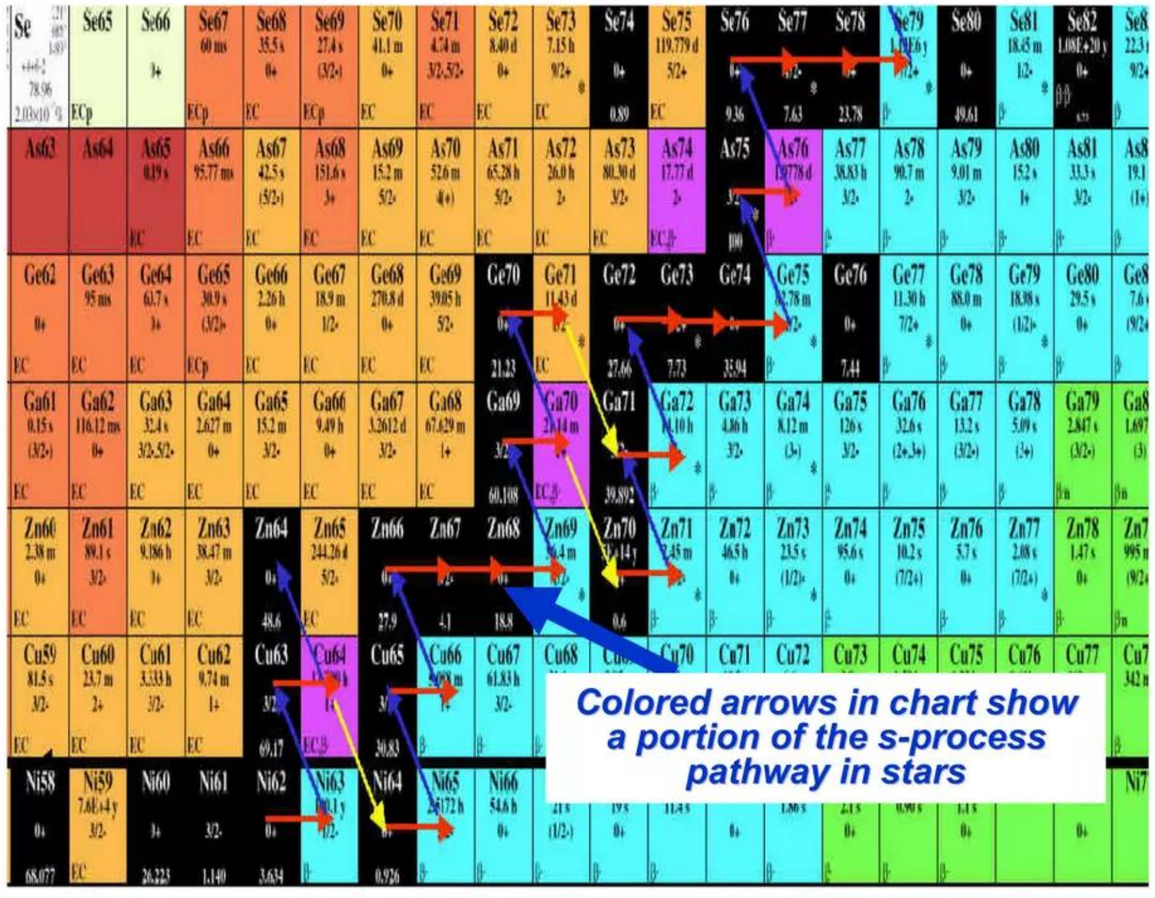
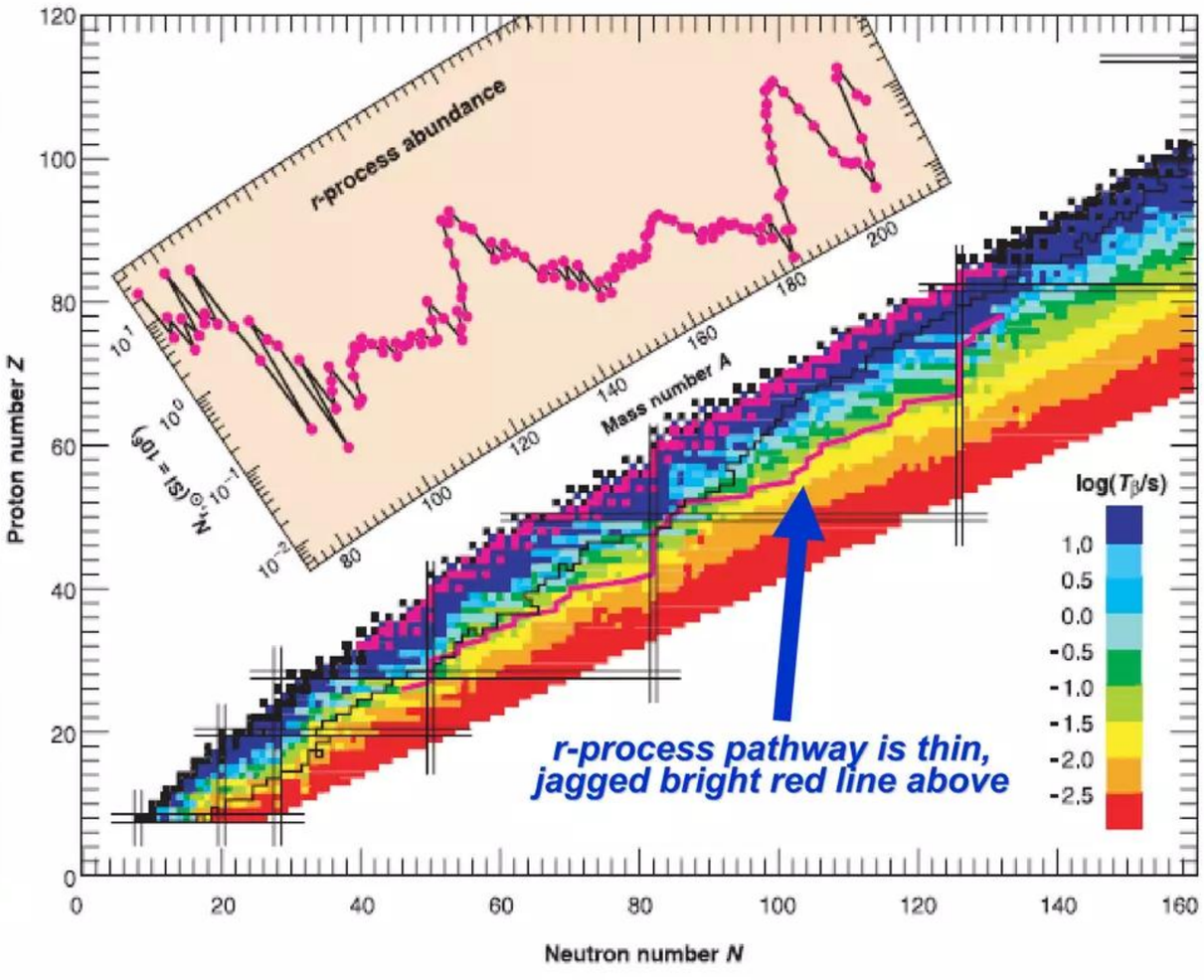
Astrophysics: neutron-capture nucleosynthesis in stars

Partial details of s-process in stars



Overall r-process in stars



Note: stellar s- and r-process element abundance peaks generally differ somewhat from those produced in LENR experimental systems on earth

Above r-process figure is from Sneddon and Cowen, "Genesis of the Heaviest Elements in the Milky Way Galaxy" Science 299, 70 (2003)

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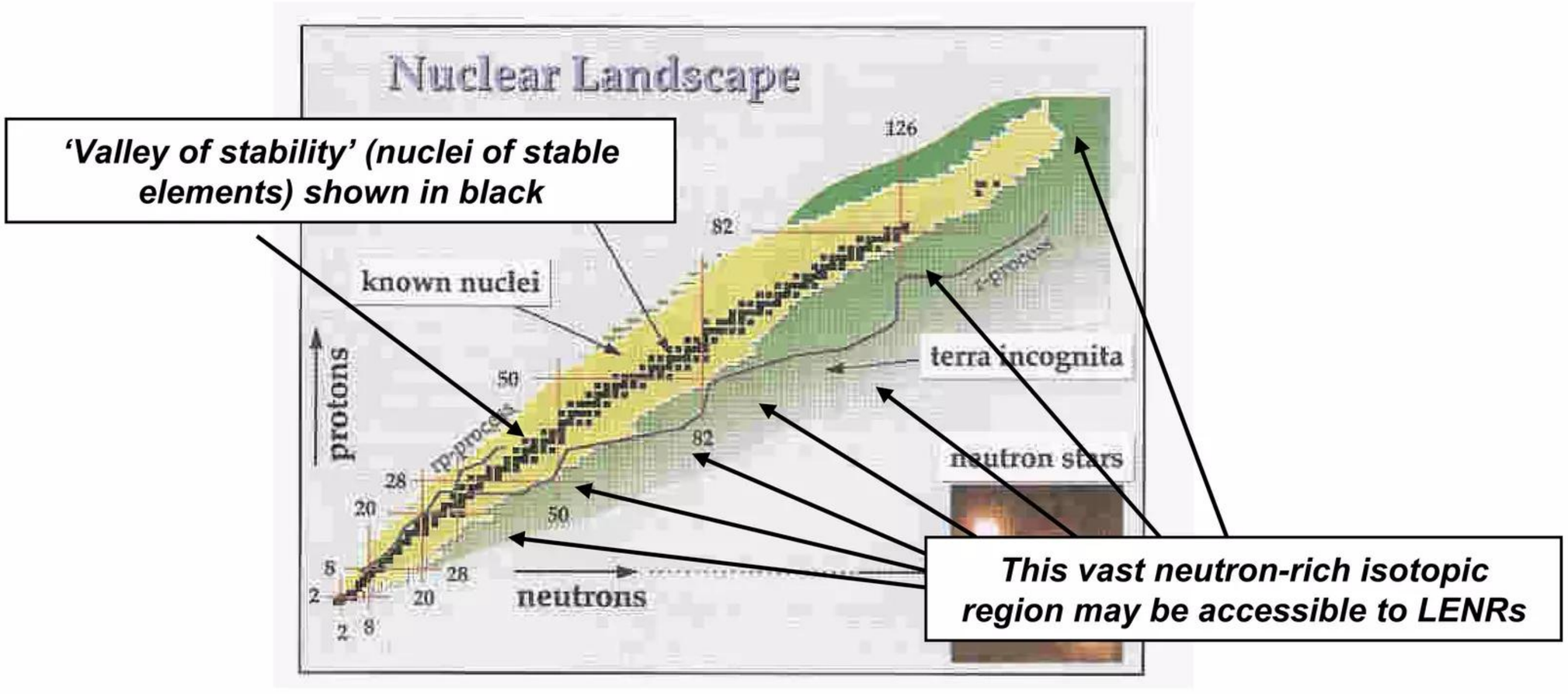
Vast isotopic parameter space may be accessible to LENRs

'Map' of stable and unstable isotopes that could be produced in LENR condensed matter systems



***LENR neutron-catalyzed weak interaction transmutations** – involve combination of neutron production, neutron capture, and energetic beta decays of neutron-rich isotopes. LENRs can move back and forth between producing stable products in the (black) valley of stability to unstable β-decay isotopes located in neutron-rich (greenish) regions to the right of it. This is very similar to s- and r-process neutron-capture nucleosynthesis in stars, only at vastly lower temperatures/pressures*