

Magfizikai ABC

Bevezető áttekintés

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MTA KFKI RMKI, Budapest

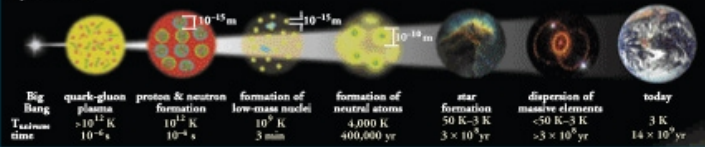
A magfizika napjainkban:
Radioaktivitás
Nukleáris energia
Maganyag és halmazállapotai
Instabil atommagok
Szupernehéz elemek
Ősrobbanás, nukleáris asztrofizika
Rádioaktív nyalábok
Új technológiák, alkalmazások

A 100 éves magfizika ABC-je

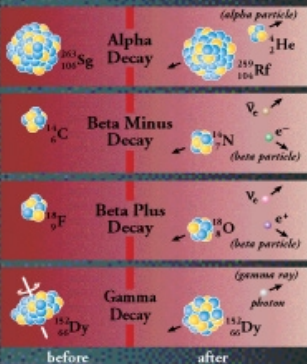
Nuclear Science

Expansion of the Universe

After the Big Bang, the universe expanded and cooled. At about 10^{-36} seconds, the universe consisted of a soup of quarks, gluons, electrons, and neutrinos. When the temperature of the Universe, T , cooled to about 10^{12} K, this soup condensed into protons, neutrons, and electrons. As time progressed, some of the protons and neutrons formed deuterium, helium, and lithium nuclei. Still later, electrons combined with protons and these low-mass nuclei to form neutral atoms. Due to gravity, clouds of atoms contracted into stars, where hydrogen and helium fused into more massive chemical elements. Exploding stars (supernovae) form the more massive elements and disperse them into space. Our earth was formed from supernova debris.



Radioactivity



Radioactive decay transforms a nucleus by emitting different particles. In alpha decay, the nucleus releases a ${}^4_2\text{He}$ nucleus—an alpha particle. In beta decay, the nucleus either emits an electron and antineutrino (for a positron and neutrino) or captures an atomic electron and emits a neutrino. A positron is the antiparticle of the electron. Antimatter is composed of anti-particles. Both alpha and beta decays change the original nucleus into a nucleus of a different chemical element. In gamma decay, the nucleus lowers its internal energy by emitting a photon—a gamma ray. This decay does not modify the chemical properties of the atom.

Chart of the Nuclides

The Chart of the Nuclides presents in graphic form all known nuclei with atomic number, Z , and neutron number, N . Each nuclide is represented by a box colored according to its predominant decay mode. Magic numbers (N or $Z = 2, 8, 20, 28, 50, 82$ and 126) are indicated by a rectangle on the chart. They correspond to major closed shells and show regions of greater nuclear binding energy.



Color Key

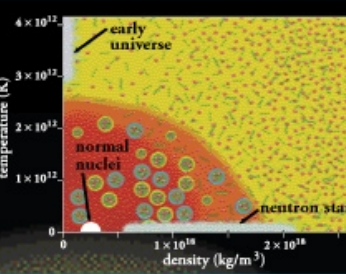
- Stable
- Spontaneous fission
- Alpha particle emission
- Beta minus emission
- Beta plus emission or electron capture

Nuclear Science is the study of the structure, properties, and interactions of the atomic nuclei. Nuclear scientists calculate and measure the masses, shapes, sizes, and decays of nuclei at rest and in collisions. They ask questions, such as: Why do neutrons stay in the nucleus? What combinations of protons and neutrons are possible? What happens when nuclei are compressed or rapidly rotated? What is the origin of the nuclei found on Earth?

Legend

- electron (e^-)
- positron (e^+)
- neutrino (ν)
- antineutrino ($\bar{\nu}$)
- quark
- gluon field
- gluon
- photon (γ)

Atomic Number Z
Neutron Number N
Mass Number $A = Z + N$



Phases of Nuclear Matter

Nuclear matter can exist in several phases. When collisions excite nuclei, individual protons and neutrons may evaporate from the nuclear fluid. At sufficiently high temperature or density, a gas of nucleons (and background) forms. At even more extreme conditions, individual nucleons may cease to have meaningful identities, merging into the quark-gluon plasma (yellow background). Current data provide hints that physicists have glimpsed the quark-gluon plasma.

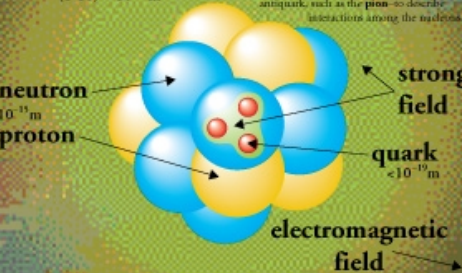
Unstable Nuclei

Stable nuclides form a narrow white band on the Chart of the Nuclides. Scientists produce unstable nuclides far from this band and study their decay, thereby learning about the extremes of nuclear conditions. In its present form, this chart contains about 2400 different nuclides. Nuclear theory predicts that there are at least 4000 more to be discovered with $Z \leq 112$.

Element 112

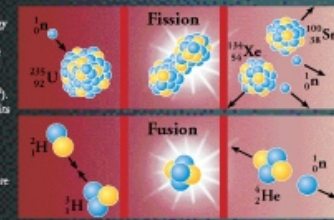
Scientists first synthesized Element 112 in a particle accelerator experiment. They identified it by observing its characteristic six alpha particle decay chain.

The Nucleus



In an atom, electrons orbit the nucleus at distances typically up to 10^{-10} m, the nuclear diameter. If the electron cloud were allowed to wake, this diagram would show a small sphere.

Nuclear Energy



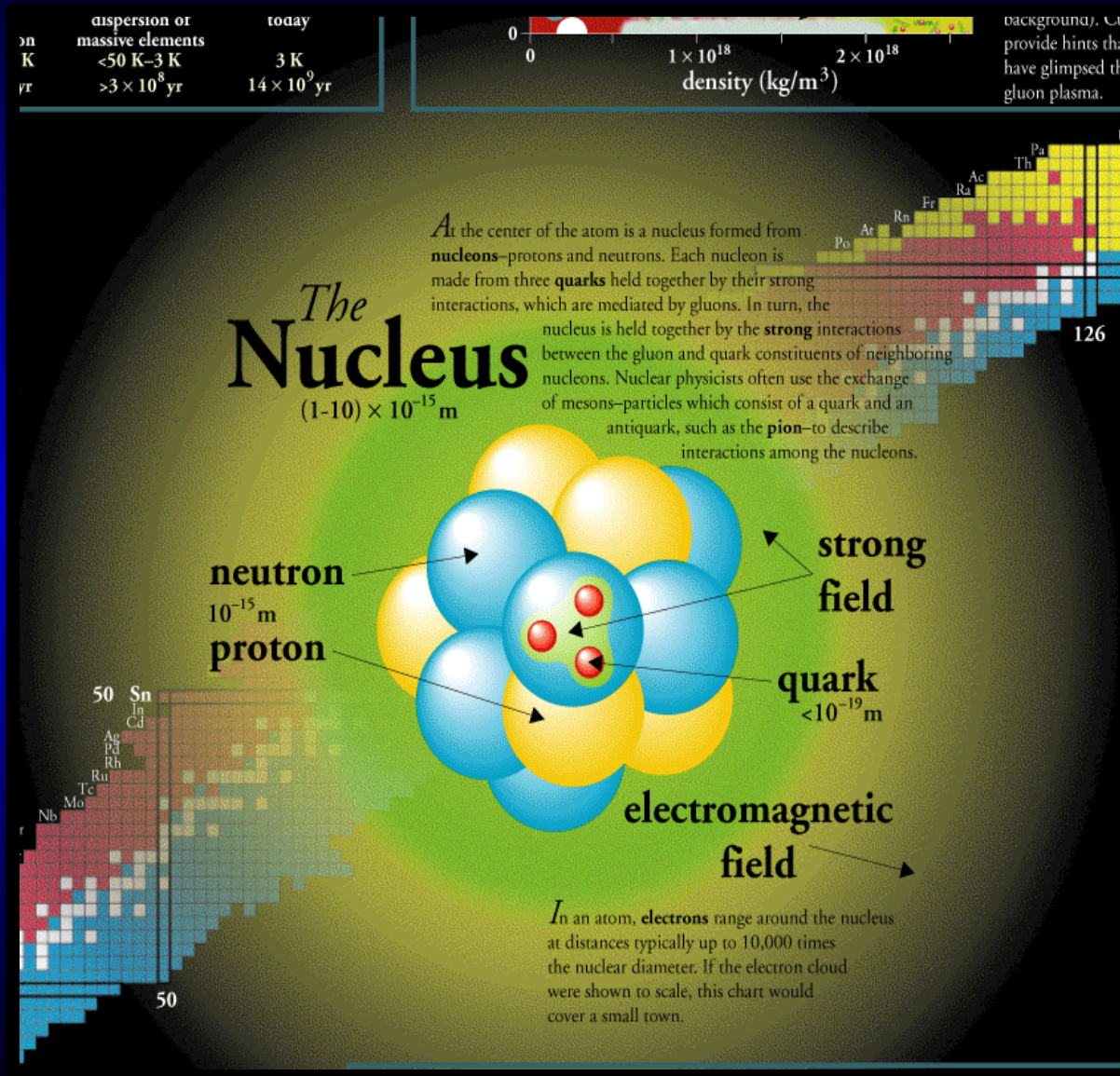
In the early stages of stellar evolution of our sun and other stars, hydrogen fuses to form helium, releasing energy in the form of photons (light) and neutrinos. During the later stages of stellar evolution, more massive nuclei up to and beyond uranium are synthesized by fusion. By measuring the number of neutrinos that come from the Sun, scientists recently have demonstrated that neutrinos must have a mass greater than zero.

Applications



Astrophysical pictures courtesy NASA/JPL/Caltech and AURA/STScI.

Atom és atommag



**E. Rutherford
értelmezése
Geiger-Mardsen
kísérlet, 1911**

**Atom =
elektronfelhő
+ atommag**

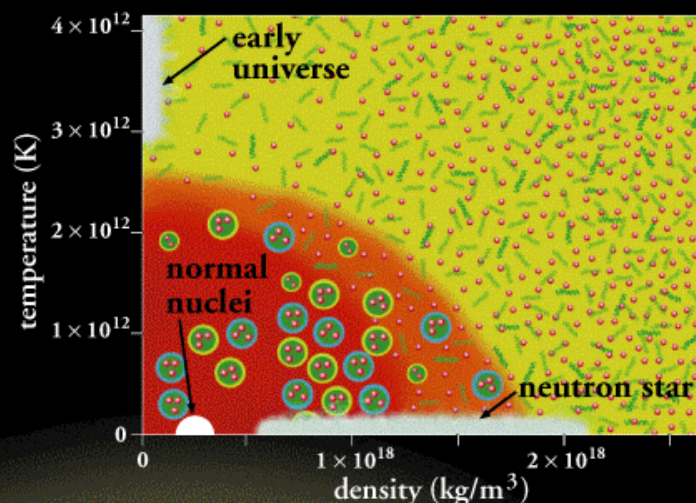
**atommag =
protonok
+ neutronok**

**erős
kölcsönhatás,
kvarkok, gluonok**

Alapvető kérdések

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Legend	● electron (e^-)	● quark	A^{mass} number
● proton	● positron (e^+)	● gluon field	Z^{atomic} number
● neutron	● neutrino (ν)	● gluon	N^{neutron} number
	● antineutrino ($\bar{\nu}$)	● photon (γ)	$N^{\text{neutron}} = A - Z$

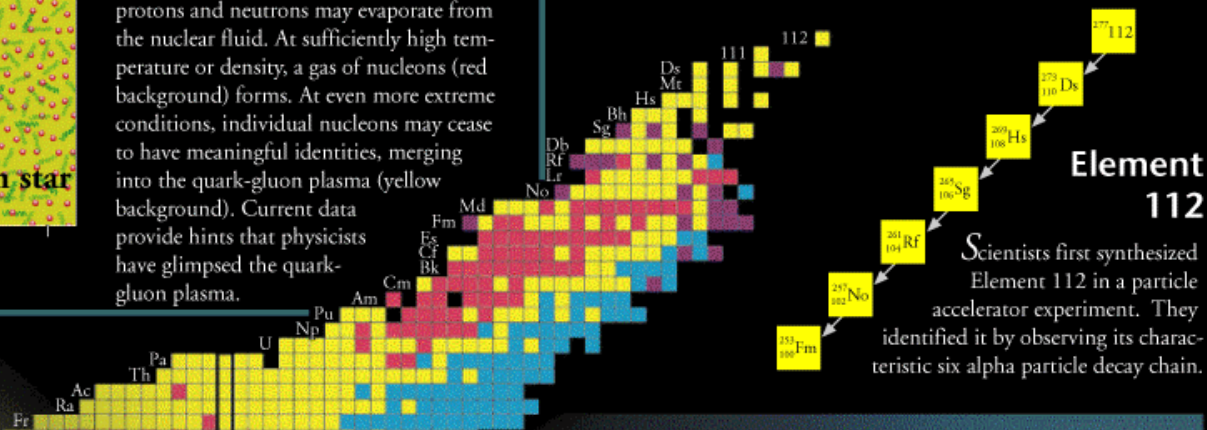


Phases of Nuclear Matter

Nuclear matter can exist in several phases. When collisions excite nuclei, individual protons and neutrons may evaporate from the nuclear fluid. At sufficiently high temperature or density, a gas of nucleons (red background) forms. At even more extreme conditions, individual nucleons may cease to have meaningful identities, merging into the quark-gluon plasma (yellow background). Current data provide hints that physicists have glimpsed the quark-gluon plasma.

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Element 112

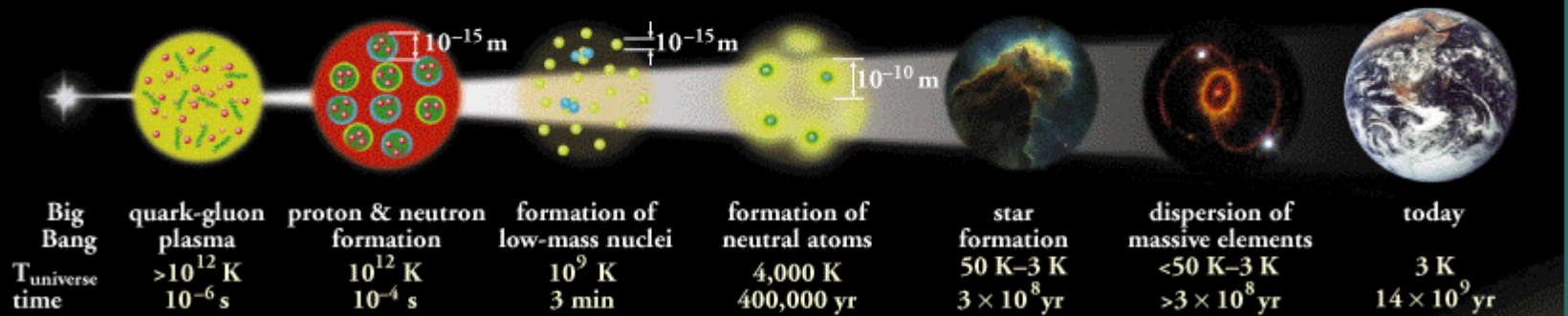
Scientists first synthesized Element 112 in a particle accelerator experiment. They identified it by observing its characteristic six alpha particle decay chain.

Az atommag szerkezete, tulajdonságai, kölcsönhatásai, pl: tömeg, alak, méret, bomlások, ütközések, reakciók, halmazállapotok, extrém körülmények, mesterséges elemek.

Világegyetem összetétele, ősrobbanás

Expansion of the Universe

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Ősrobbanás elmélet pillérei:

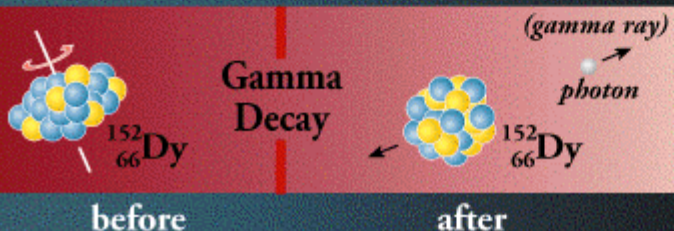
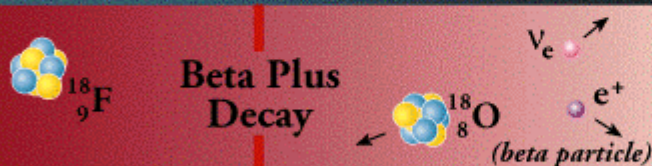
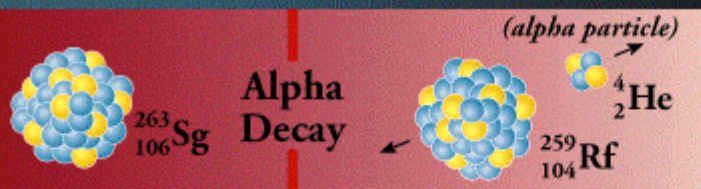
A Hubble törvény, $v = H r$. A világegyetem tágul.

A kozmikus elemgyakoriság: magfizika

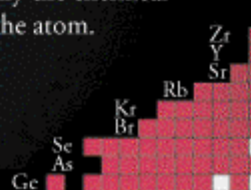
Kozmikus háttérsugárzás homogén, izotróp.

Rádióaktivitás

Radioactivity



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E. Rutherford osztályozása:

α , β , és γ sugárzás

áthatoló képesség

és töltés alapján

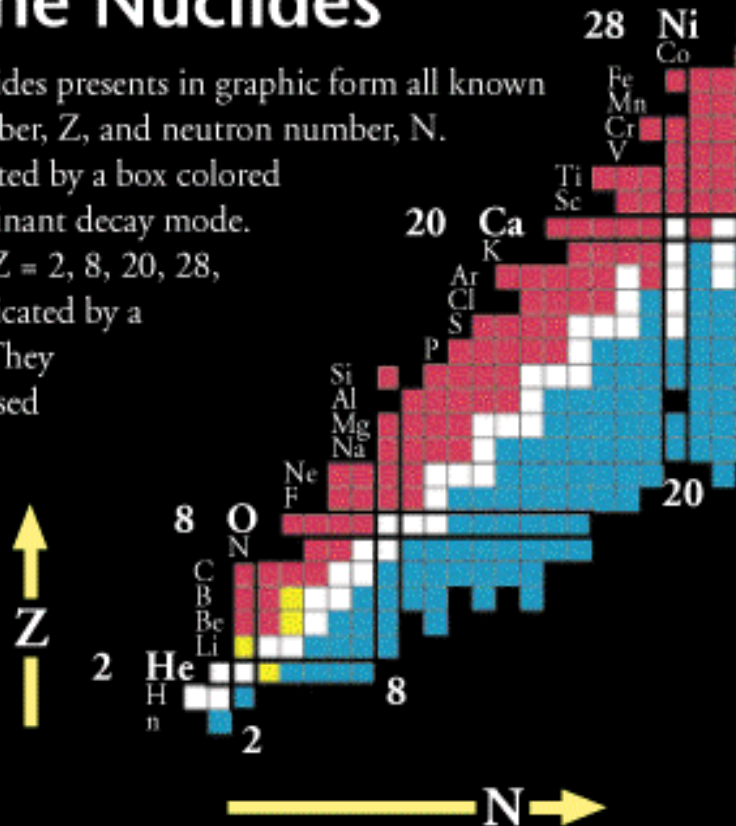
Az atommagok völgye

Chart of the Nuclides

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Az atommagok osztályozása:

N = neutrons szám

Z = protons szám

szín → fő bomlás

mágikus számok:

**N vagy Z =
2, 8, 20, 28, 50,
82, 126**

A magfizika alkalmazásai

Applications



Radioactive Dating

Naturally occurring radioactive isotopes such as ^{14}C are used to date objects that were once living, such as wood. For example, from a study of artifacts found at the site, scientists determined that Stonehenge was built nearly 4,000 years ago.



Space Exploration

Sojourner used alpha particles to identify chemical elements present in Martian rocks. On Earth, nuclear reactions are used in many areas from criminal investigations to art authentication.



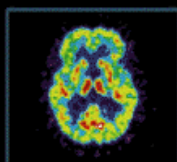
Nuclear Reactors

Nuclear reactors use the fission of ^{235}U or ^{239}Pu nuclei to produce electric power. Reactors and most other nuclear applications generate radioactive waste; disposal of this waste is a subject of current research.



Smoke Detectors

Many smoke detectors use a small amount of the alpha emitter ^{241}Am to ionize the air. Smoke entering the detector reduces the current and sets off the alarm.



Nuclear Medicine

Radioactive isotopes, such as $^{99\text{m}}_{43}\text{Tc}$, $^{60}_{27}\text{Co}$ and $^{131}_{53}\text{I}$, are commonly used in the diagnosis and treatment of disease. Positron emitters such as ^{18}F are used in Positron Emission Tomography (PET) to generate images of brain activity.



Magnetic Resonance Imaging

Magnetic Resonance Imaging (MRI) makes use of atomic transitions involving the magnetic field of a nucleus to study the local chemical environment. This technique accurately maps the density of hydrogen to produce three-dimensional images of the human body.

Astrophysical pictures courtesy NASA/JPL/Caltech and AURA/STScI.

Radioaktív kormeghatározás
Űrkutatás

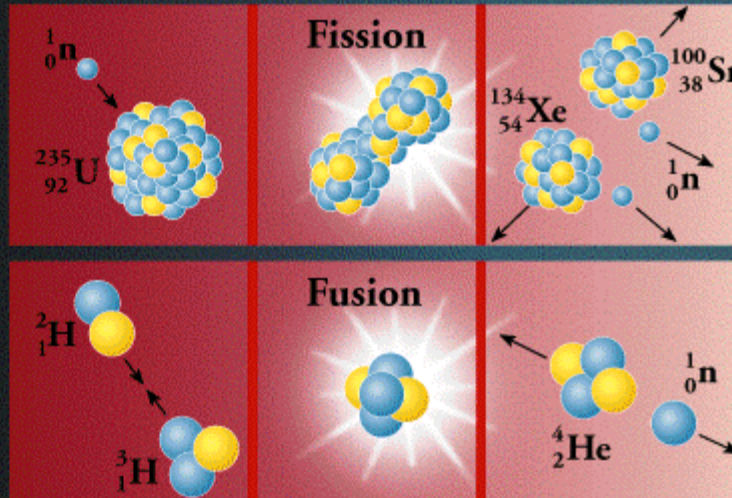
Atomenergia, atomerőművek
Füstdetektorok

Radioaktív nyomjelzés, orvosi izotópok
Magmágneses rezonancia, képalkotás

Az atom(mag)energia

6 Nuclear reactions release energy when the total mass of the products is less than the sum of the masses of the initial nuclei. The "lost mass" appears as kinetic energy of the products ($E = mc^2$). In fission, a massive nucleus splits into two major fragments that usually eject one or more neutrons. In fusion, low mass nuclei combine to form a more massive nucleus plus one or more ejected particles—neutrons, protons, photons, or alpha particles.

Nuclear Energy



In the early stages of stellar evolution of our sun and other stars, hydrogen fuses to form helium, releasing energy in the form of photons (light) and neutrinos. During the later stages of stellar evolution, more massive nuclei up to and beyond uranium are synthesized by fusion. By measuring the number of neutrinos that come from the Sun, scientists recently have demonstrated that neutrinos must have a mass greater than zero.



$$E = mc^2$$

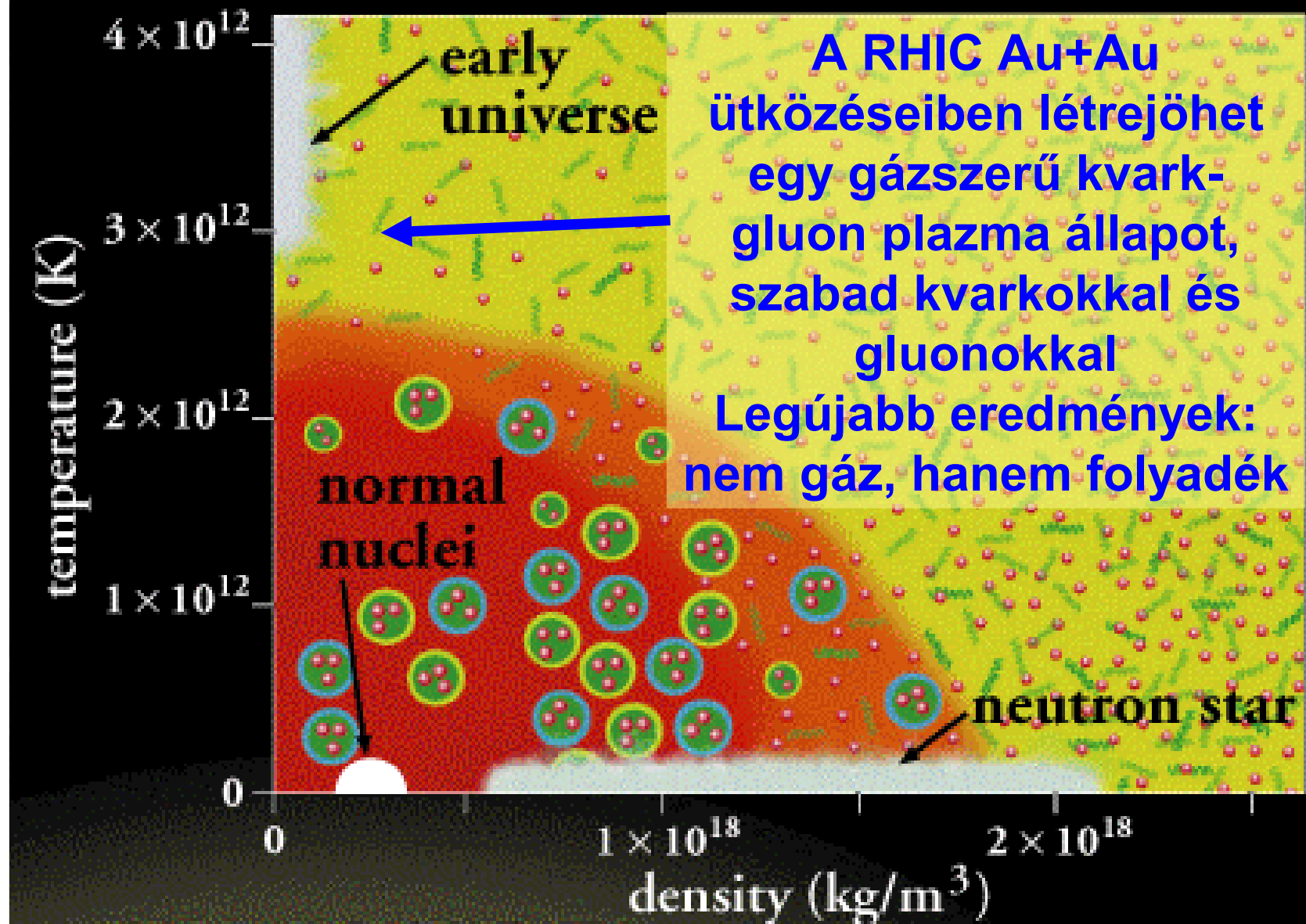
Rutherford,
Szilárd,
Einstein

tömegkülönbség
→ energia

magfúzió
maghasadás
láncreakció

csillagok
energiatermelése

Várakozás 2000 körül



Ajánlott irodalom

Bevezető művek:

Csörgő J., Török Cs., Csörgő T.:

Részecskés kártyajáték – elemi részecskék, játékosan

<http://www.lulu.com/spotlight/Reszecskeskartya>

R. Mackintosh, J. Al-Khalili, B. Johnson, T. Pena:

Az atommag: utazás az anyag szívébe

Marx Gy.: Atommagközelben

K. N. Muhin: Magfizika mindenkinek

Nuclear Physics wall chart

<http://www.lbl.gov/abc/>

Részletesebb információ:

Raics P: Bevezetés a mag- és részecskefizikába

<http://fizika.ttk.unideb.hu/kisfiz/Raics>

Kiss D., Horváth Á., Kiss Á.:

Kísérleti atomfizika, ELTE Eötvös Kiadó, 1998

K.N. Muhin: Kísérleti magfizika, Tankönyvkiadó, 1985

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