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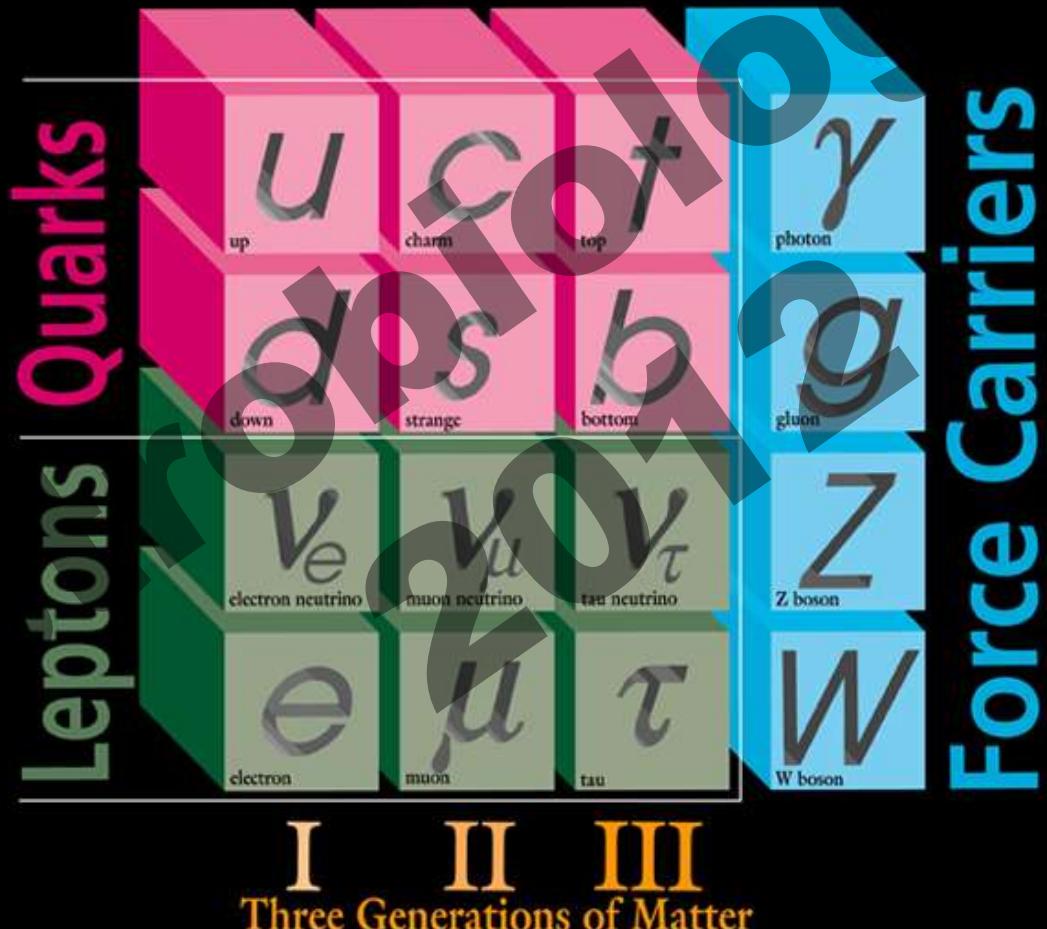
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10. 8. 2012.

Astrobiologija 2012

POREKLO HEMIJSKIH ELEMENATA

ELEMENTARY PARTICLES



PERIODNI SISTEM



DMITRIJ MENDELJEJEV 1869 – NAJVEĆE OTKRIĆE U ISTORIJI HEMIJE

IA		IIA																0																						
1	H	3	Be															2	He																					
2	Li	11	Mg	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36												
3	Na	12	Mg	11	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36												
4	K	19	Ca	20	Sc	Ti	Y	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	37	Rb	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	Xe
5	Rb	37	Sr	38	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	55	Cs	56	57	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	Rn
6	Cs	55	Ba	56	*La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	87	Fr	88	89	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119
7	Fr	87	Ra	88	+Ac	Rf	Ha	106	107	108	109	110	111	112	113	114	115	116	117	118	119																			

Naming conventions of new elements

* Lanthanide Series

+ Actinide Series

58	Ce	59	Pr	60	Nd	61	Pm	62	Sm	63	Eu	64	Gd	65	Tb	66	Dy	67	Ho	68	Er	69	Tm	70	Yb	71	Lu
90	Th	91	Pa	92	U	93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf	99	Es	100	Fm	101	Md	102	No	103	Lr

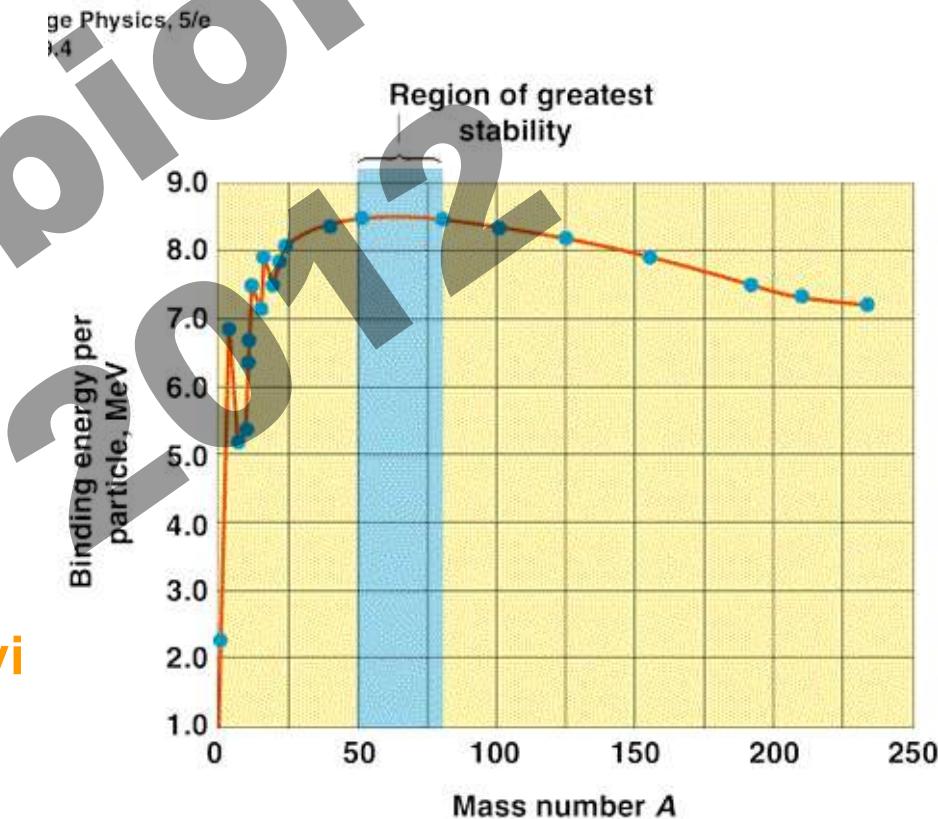
Z = atomski broj (broj protona)

A = maseni broj (broj protona + neutrona)

KAKO SU NASTALA ATOMSKA JEZGRA?

○ Stvaranje jezgara = **nukleosinteza!**

- ◆ Podrazumeva se da je nastanak jezgara istovremeno i nastanak atoma!
- ◆ Ključ = **nuklearna stabilnost**
- ◆ Laki elementi teže da se **spajaju**, teški da se **cepaju**
- ◆ **Gde mogu postojati takvi uslovi?**



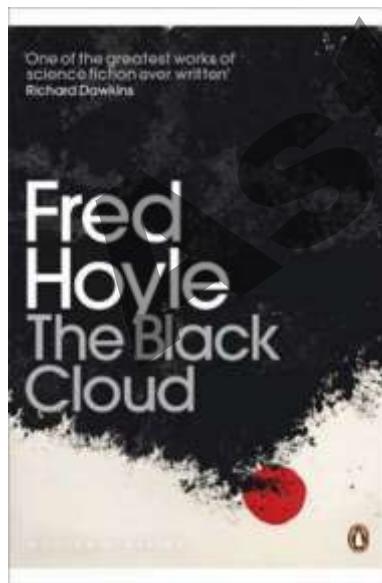
DVA GENIJA REŠAVAJU STVAR...



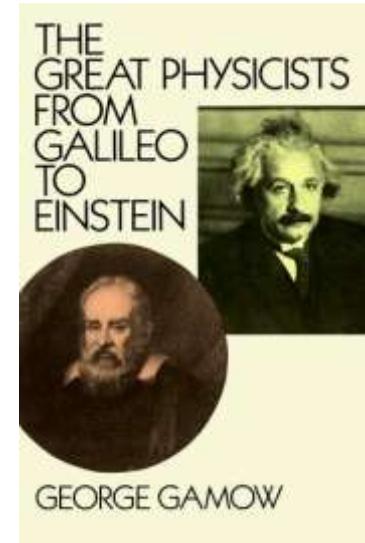
Ser Fred Hojl (1915-2001)

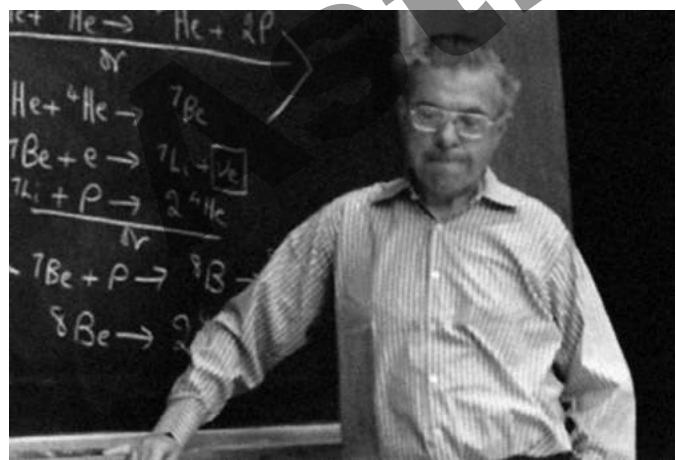


Georgij (Džordž) Antonovič
Gamov (1904-1968)



I am glad to say
that it won't necessary
any more to pour
Hoil on the troubled
waters of cosmogony.
G. Gamow





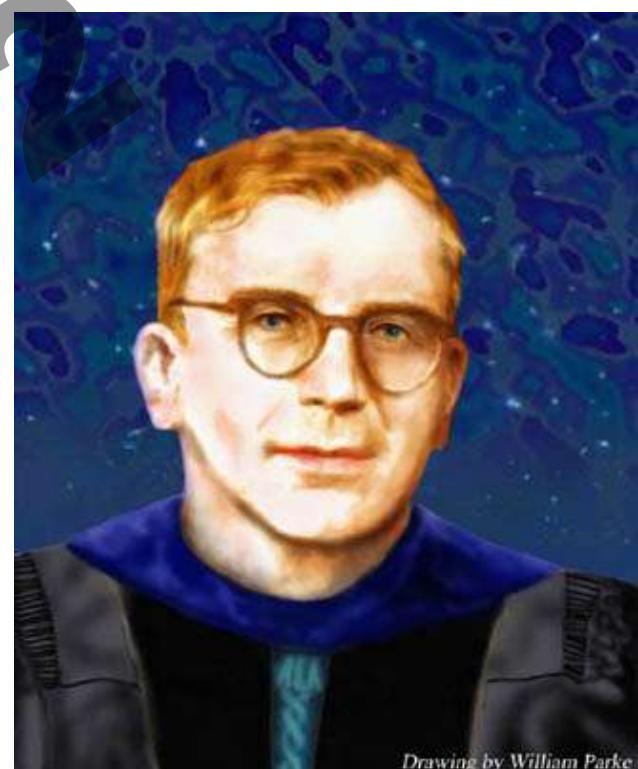
Astrobiologija

2012



GENIJE IZ ODESE

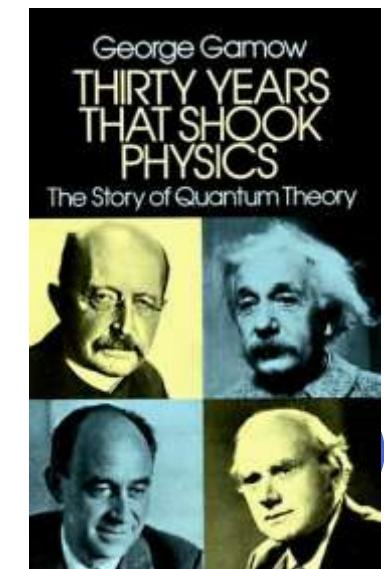
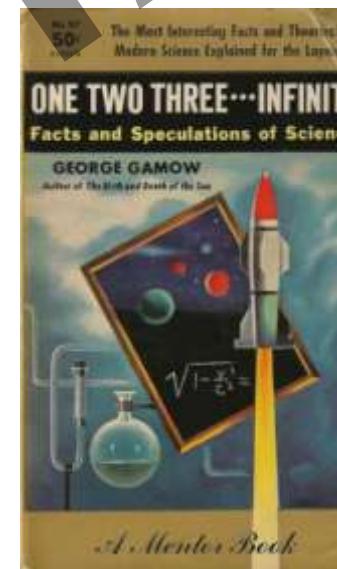
- Studirao kod Fridmana do 1925, potom kod Bora i Raderforda
- „Tri musketara“: Gamov i
 - Lev Landau
 - Dmitrij Ivanjenko
 - Matvej Bronštajn
- 1931. postao najmlađi član Sovjetske akademije u istoriji – i zabranjeno mu da putuje (!)
- Dvaput pokušao da pobegne **kajakom**...
- 1933. prvi Solvejev kongres, dobija pomoć od Marije Kiri
- Od 1934. živi u SAD, najpre GWU (Sent Luis), a poslednjih godina UC (Boulder)
- Poslednjih godina težak alkoholičar, iznenada umire u Boulderu 1968.



Drawing by William Parke

VELIKO DELO...

- Rešenje problema kvantnog tuneliranja
- Gamovljev faktor u alfa-raspadu
- Nuklearni model kapi
- Nastanak Sunčevog sistema
- Prvi sugerisao triplete u DNK/RNK kao „reči“
- Primordijalna nukleosinteza
- Veliki popularizator nauke!





Astrofisiologija





the Sept 29th 1963

Gamow Dacha
785 - 8th Street
Boulder, Colorado

Dear Dr. Penzias,

Send Thank you for sending me your paper on 3°K radiation. It is very nicely written except that "early history" is not "quite complete". The theory of what is now known as "primeval fireball" was first developed by me in 1946 (Phys. Rev. 70, 572, 1946; 74, 505, 1948; Nature 162, 680, 1948). The prediction of the numerical value of the present (residue) temperature could be found in Alpher & Bethe's paper (Phys. Rev. 75, 1093, 1949) who estimate it as 5 $^{\circ}\text{K}$, and in my paper (Kong Dansk. Ved. Sels. 27 no 10, 1953) with the estimate of 7 $^{\circ}\text{K}$. Even in my popular book "Creation of Universe" (Viking 1952) you can find (on p. 42) the formula $T = 1.5 \cdot 10^{10} / t^{1/2}$ $^{\circ}\text{K}$, and the upper limit of 50 $^{\circ}\text{K}$. Thus, you see the word did not start with almighty Dicke. Sincerely G. Gamow?

Astrobiologija

$\alpha\beta\gamma$ teorija

- Alferova doktorska dizertacija
- Gamovljeva šala sa Beteom
- Zahvat neutra na kao osnovni proces
- „Svi hemijski elementi nastali su za kraće vreme nego što je domaćici potrebno da skuva ručak.“
- Hojl sreću kvari: nema $A = 5$ (i drugih masenih procepa)!
- Bete → Zaharijus ☺

Letters to the Editor

PUBLICATION of brief reports of important discoveries in physics may be secured by addressing them to this department. The closing date for this department is five weeks prior to the date of issue. No proof will be sent to the authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents. Communications should not exceed 600 words in length.

The Origin of Chemical Elements

R. A. ALFRED^a
Applied Physics Laboratory, The Johns Hopkins University,
Silver Spring, Maryland

H. BETHE^b
Cornell University, Ithaca, New York

G. GAMOW^c
The George Washington University, Washington, D. C.
February 18, 1948

As pointed out by one of us,¹ various nuclear species must have originated not as the result of equilibrium corresponding to a certain temperature and density, but rather as a consequence of a continuous building-up process arrested by a rapid expansion and cooling of the primordial matter. According to this picture, we must imagine the early stage of matter as a highly compressed neutron gas (overheated neutral nuclear fluid) which started decaying into protons and electrons when the gas pressure fell down as the result of universal expansion. The radiative capture of the still remaining neutrons by the newly formed protons must have led first to the formation of deuterium nuclei, and the subsequent neutron captures resulted in the building up of heavier and heavier nuclei. It must be remembered that, due to the comparatively short time allowed for this process,² the building up of heavier nuclei must have proceeded just above the upper fringe of the stable elements (short-lived Fermi elements), and the present frequency distribution of various atomic species was attained only somewhat later as the result of adjustment of their electric charges by β -decay.

Thus the observed slope of the abundance curve must not be related to the temperature of the original neutron gas, but rather to the time period permitted by the expansion process. Also, the individual abundances of various nuclear species must depend not so much on their intrinsic stabilities (mass defects) as on the values of their neutron capture cross sections. The equations governing such a building-up process apparently can be written in the form:

$$\frac{dn_i}{dt} = f(t)(\sigma_{i-1}n_{i-1} - \sigma_i n_i) \quad (i = 1, 2, \dots, 238) \quad (1)$$

where n_i and σ_i are the relative numbers and capture cross sections for the nuclei of atomic weight i , and where $f(t)$ is a factor characterizing the decrease of the density with time.

We may remark at first that the building-up process was apparently completed when the temperature of the neutron gas was still rather high, since otherwise the observed abundances would have been strongly affected by the resonances in the region of the slow neutrons. According to Hughes,³ the neutron capture cross sections of various elements (for neutron energies of about 1 Mev) increase exponentially with atomic number halfway up the periodic system, remaining approximately constant for heavier elements.

Using these cross sections, one finds by integrating Eqs. (1) as shown in Fig. 1 that the relative abundances of various nuclear species decrease rapidly for the lighter elements and remain approximately constant for the elements heavier than silver. In order to fit the calculated curve with the observed abundances⁴ it is necessary to assume the integral of ρdt during the building-up period is equal to 5×10^4 g sec./cm.³

On the other hand, according to the relativistic theory of the expanding universe⁵ the density dependence on time is given by $\rho \leq 10^{10}/t^3$. Since the integral of this expression diverges at $t=0$, it is necessary to assume that the building-up process began at a certain time t_0 satisfying the relation:

$$\int_{t_0}^{\infty} (10^4/\rho) dt \leq 5 \times 10^4 \quad (2)$$

which gives us $t_0 \leq 20$ sec., and $\rho_0 \leq 2.5 \times 10^4$ g sec./cm.³ This result may have two meanings: (a) for the higher densities existing prior to that time the temperature of the neutron gas was so high that no aggregation was taking place, (b) the density of the universe never exceeded the value 2.5×10^4 g sec./cm.³ which can possibly be understood if we

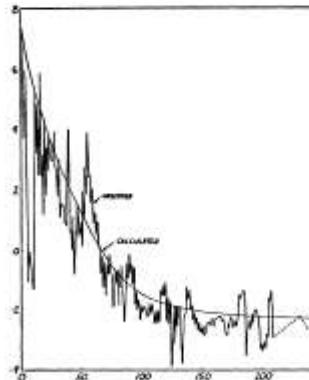


FIG. 1.
Log of relative abundance
Atomic weight.

HOJLOV ODGOVOR: ZVEZDANA NUKLEOSINTEZA!

- B^2FH članak
- Jezgra nastaju u unutrašnjostima zvezda **termonuklearnom fuzijom**
- Ovaj proces se odvija u svim vrstama zvezda, različitim intenzitetom



REVIEWS OF MODERN PHYSICS

VOLUME 29, NUMBER 4

October, 1957

Synthesis of the Elements in Stars*

MARGARET BURBIDGE, G. R. BURBIDGE, WILLIAM A. FOWLER, AND F. HOYLE
*Kellogg Radiation Laboratory, California Institute of Technology, and
Mount Wilson and Palomar Observatories, Carnegie Institution of Washington,
California Institute of Technology, Pasadena, California*

"It is the stars, The stars above us, govern our conditions";
(King Lear, Act IV, Scene 3)

but perhaps

"The fault, dear Brutus, is not in our stars, But in ourselves."
(Julius Caesar, Act I, Scene 2)

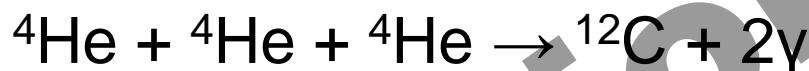
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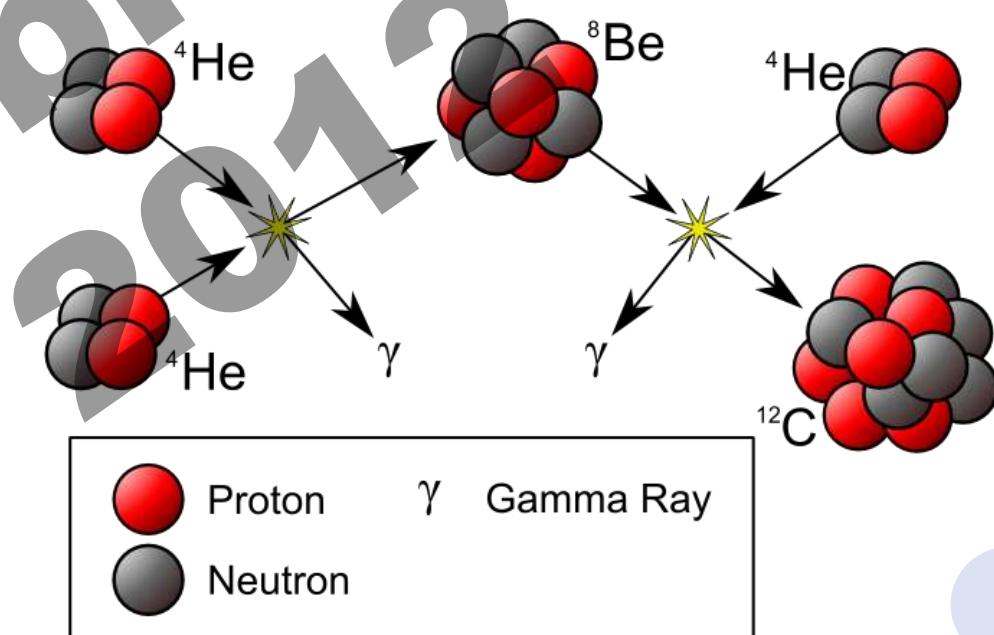
* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

OSNOVA PERIODNOG SISTEMA: "TROSTRUKA ALFA"

- Hojl (1952): reakcija koja se **mora** odigrati

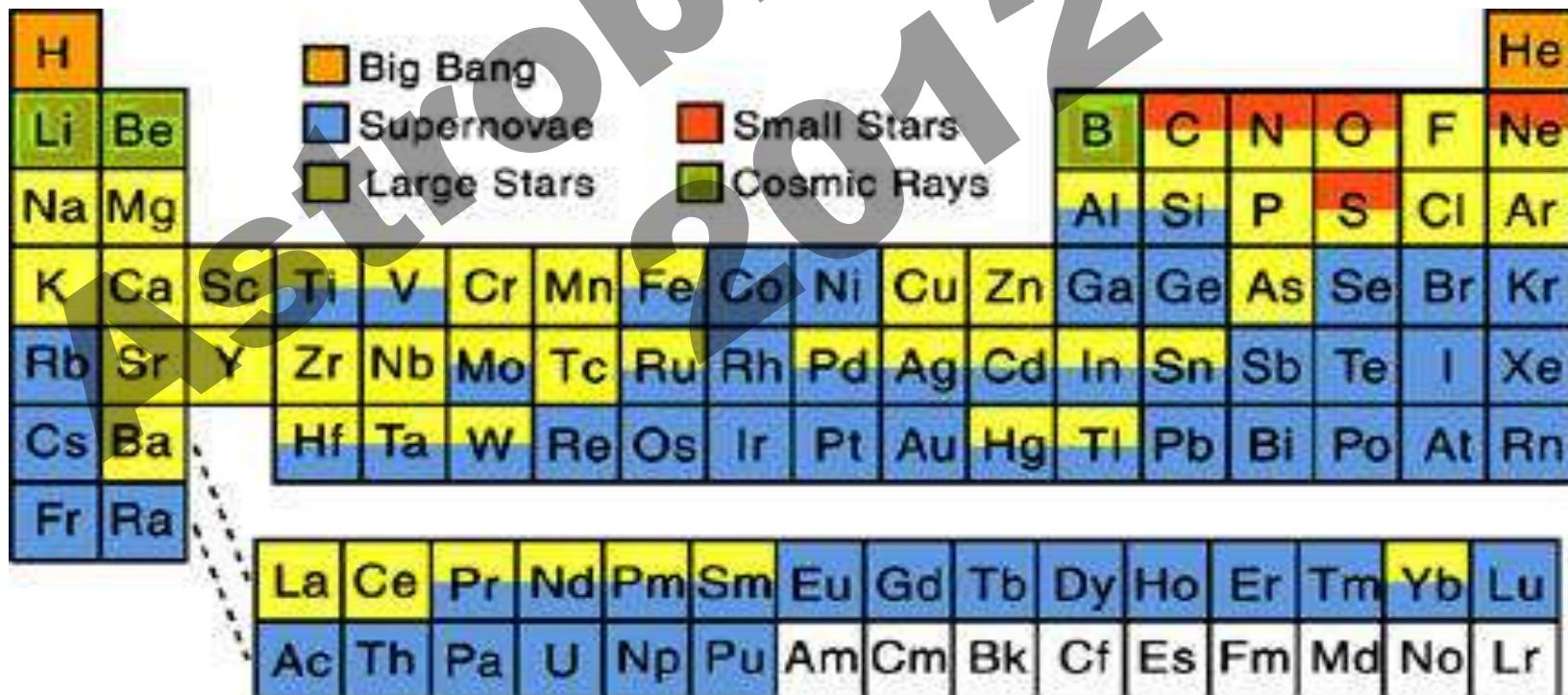
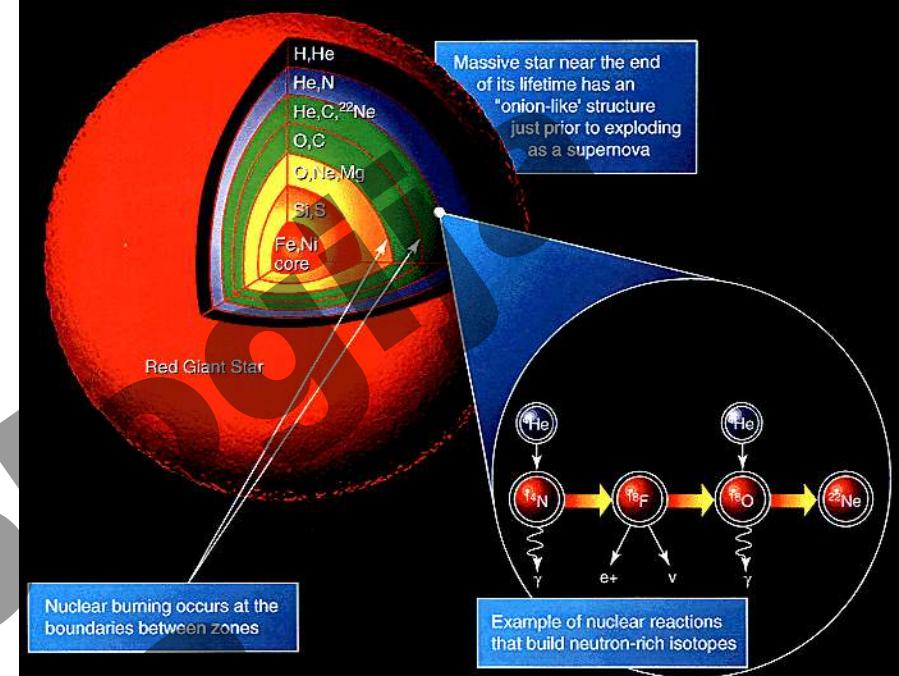


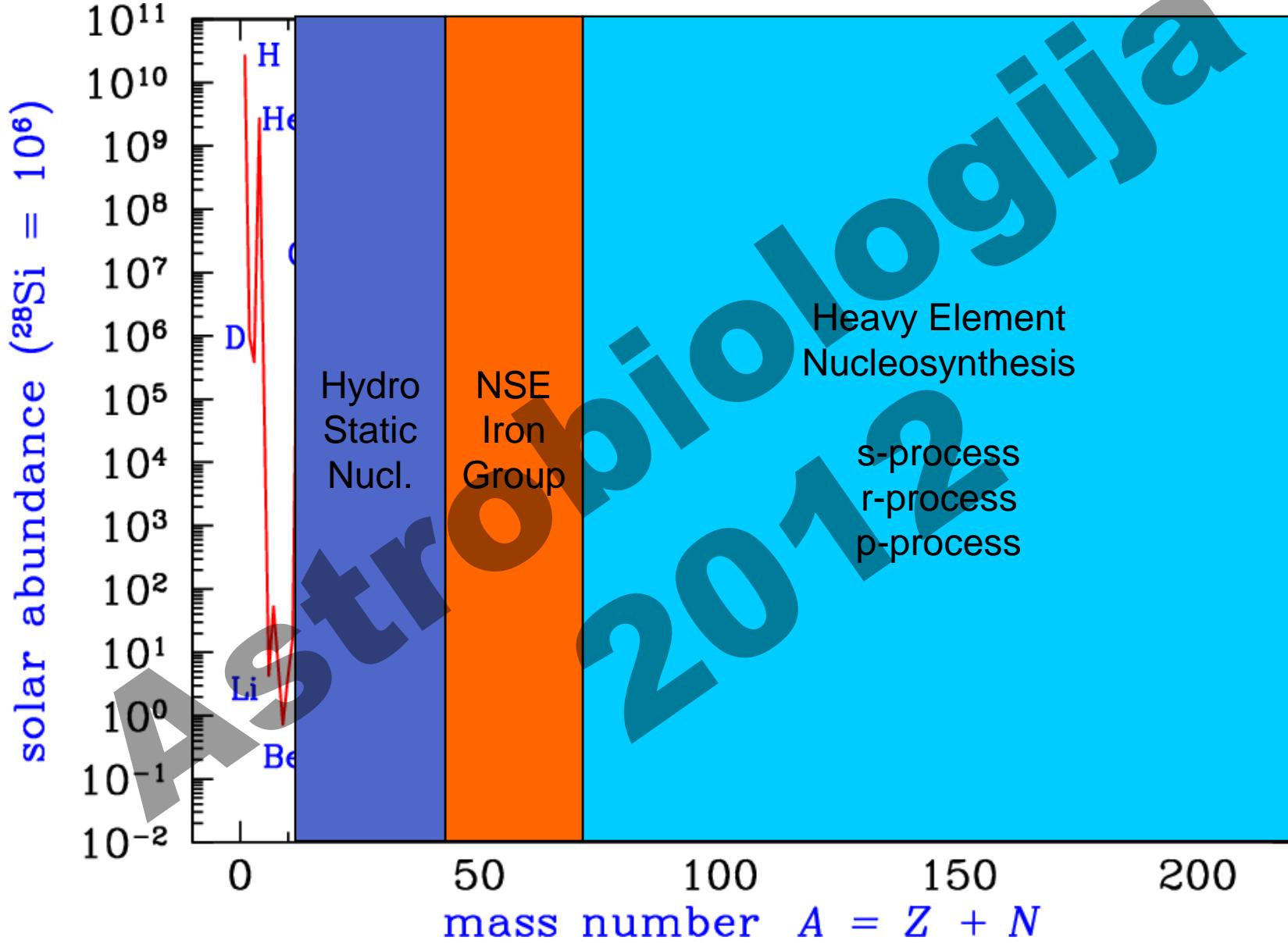
- Stopa reakcije
 $\propto T^{30}$ (!!?)



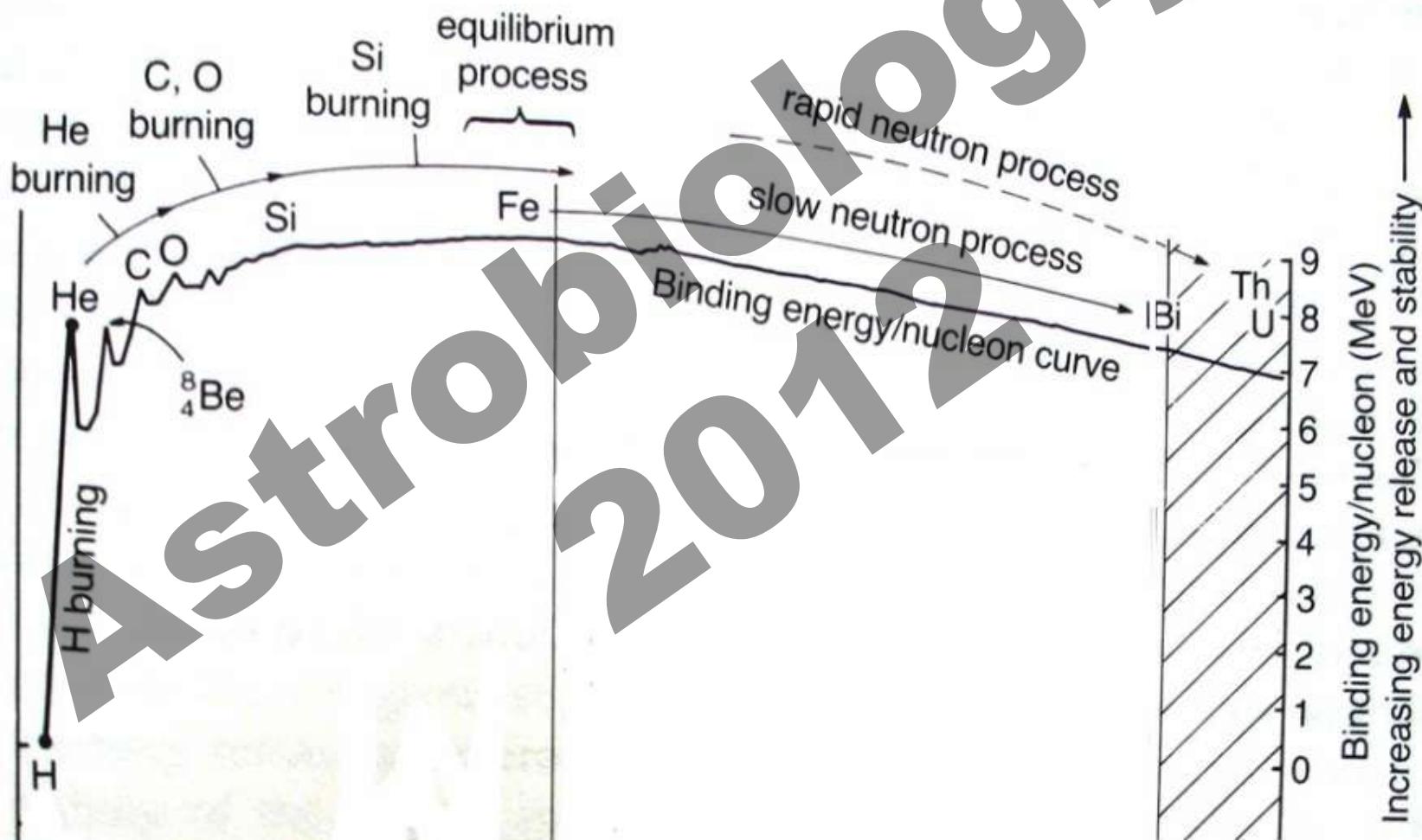
RAZNOLIKO POREKLO...

o ...različitih elemenata!





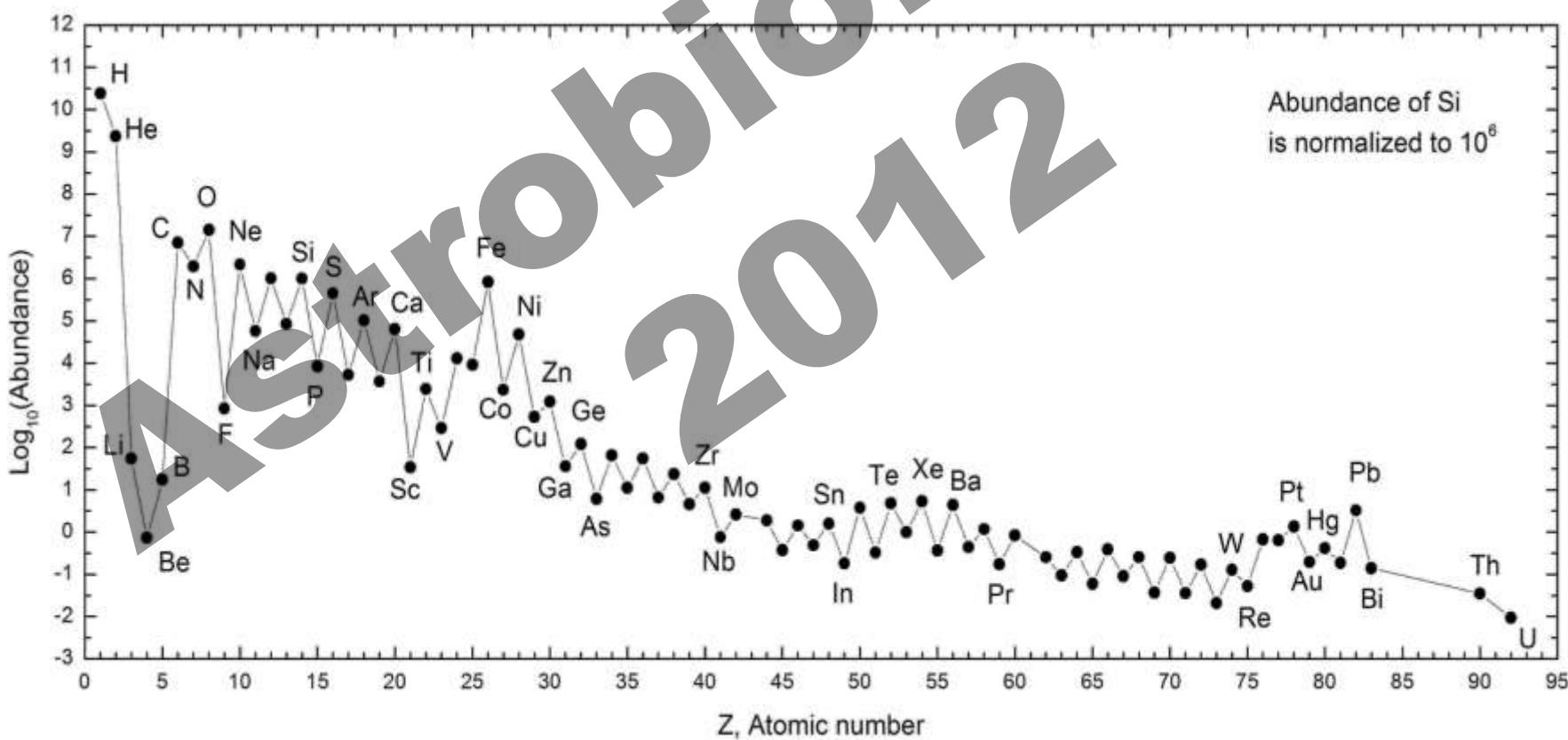
DETALJI STABILNOSTI



STANDARDNI SUNČEV HEMIJSKI SASTAV

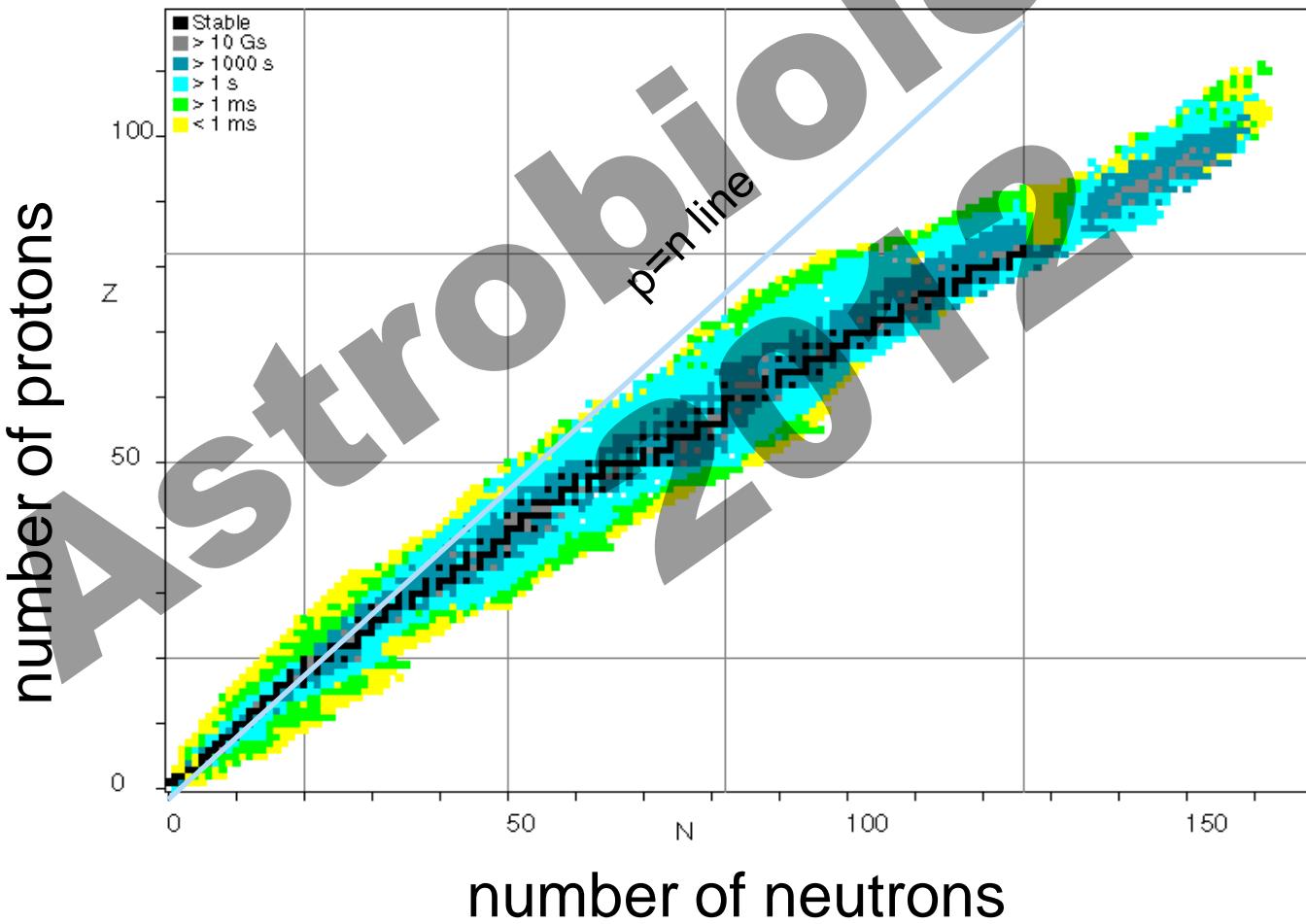


- 1) Ignorišemo tamnu stranu (Λ , CDM) svemira!
- 2) Generalno opadanje sa atomskim brojem (H najčešći, U najređi)
- 3) Velike negativne anomalije za Be, B, Li – umerena pozitivna anomalija oko Fe („gvozdeni vrh“), testerasta raspodela od parno-neparnog efekta



NUKLIDSKA MAPA

Prirodni nuklidi definišu putanju maksimalne stabilnosti: za male mase ($N = Z$), ali sa porastom A stabilni n/p odnos se povećava do $N/Z = 1.5$.

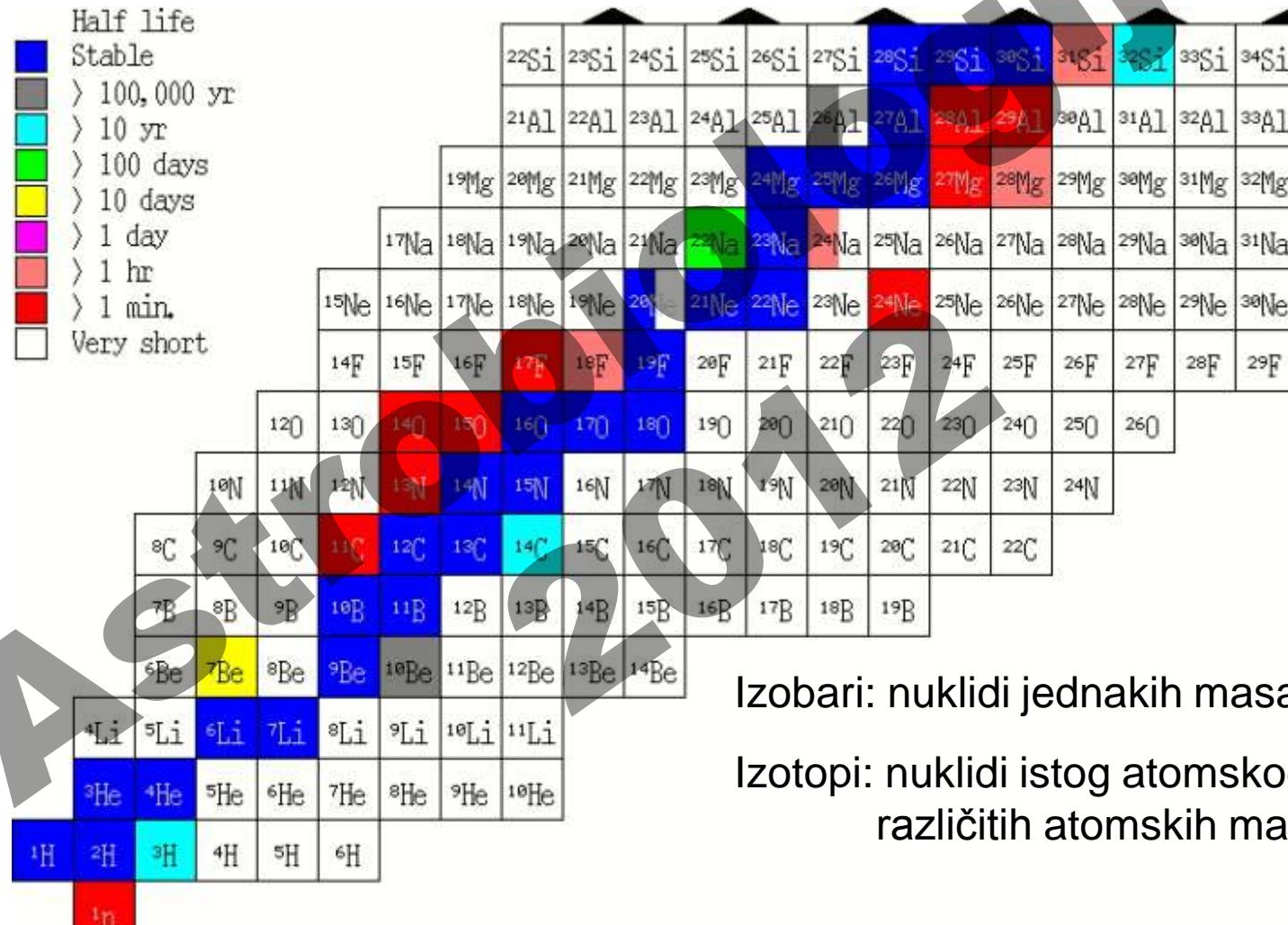


U DETALJIMA...

↑

Broj protona

- Half life
- Stable
- > 100,000 yr
- > 10 yr
- > 100 days
- > 10 days
- > 1 day
- > 1 hr
- > 1 min.
- Very short



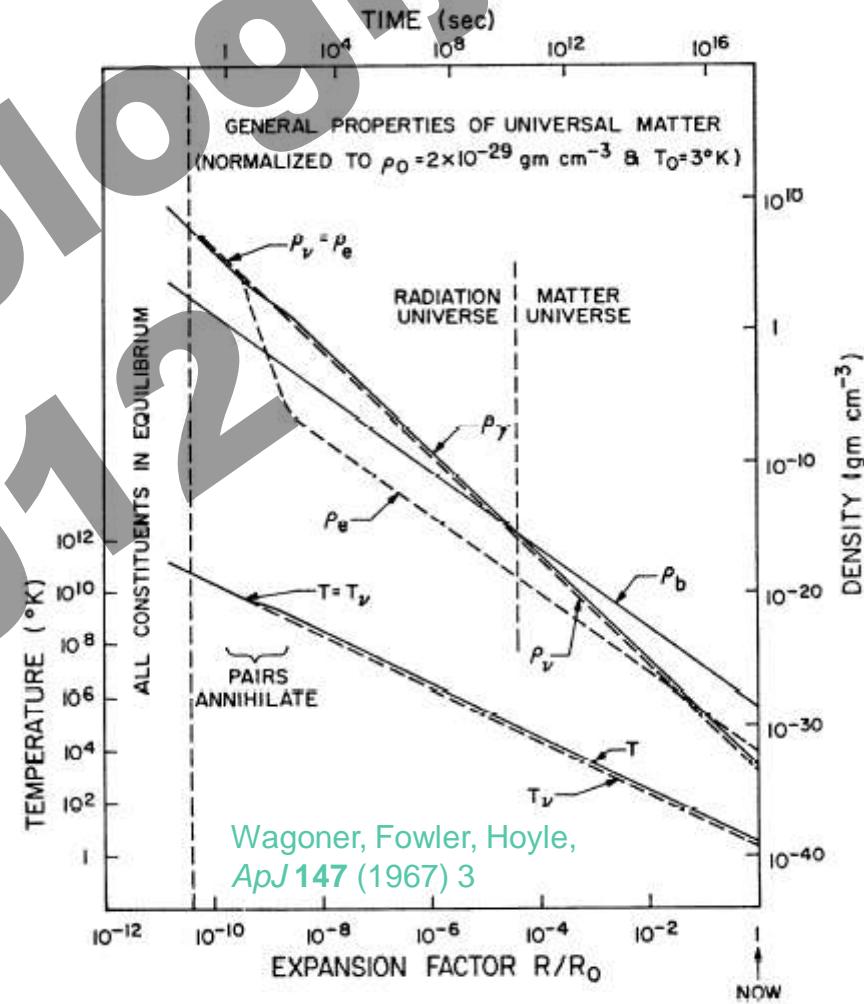
Broj neutrona →

Izobari: nuklidi jednakih masa

Izotopi: nuklidi istog atomskog broja,
različitih atomske masa

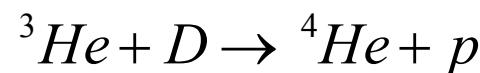
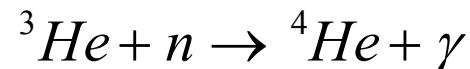
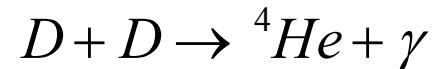
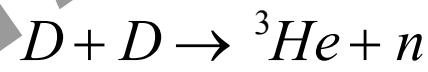
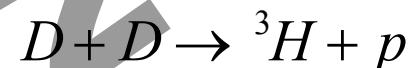
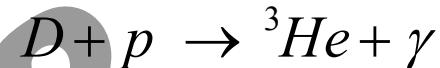
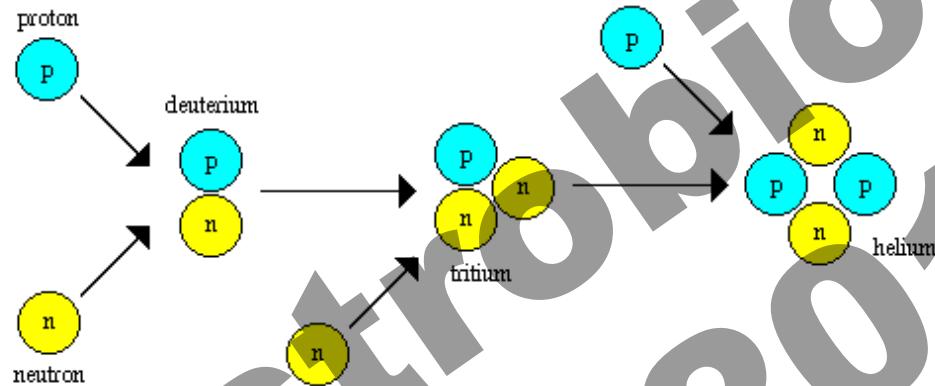
PRIMORDIJALNA NUKLEOSINTEZA

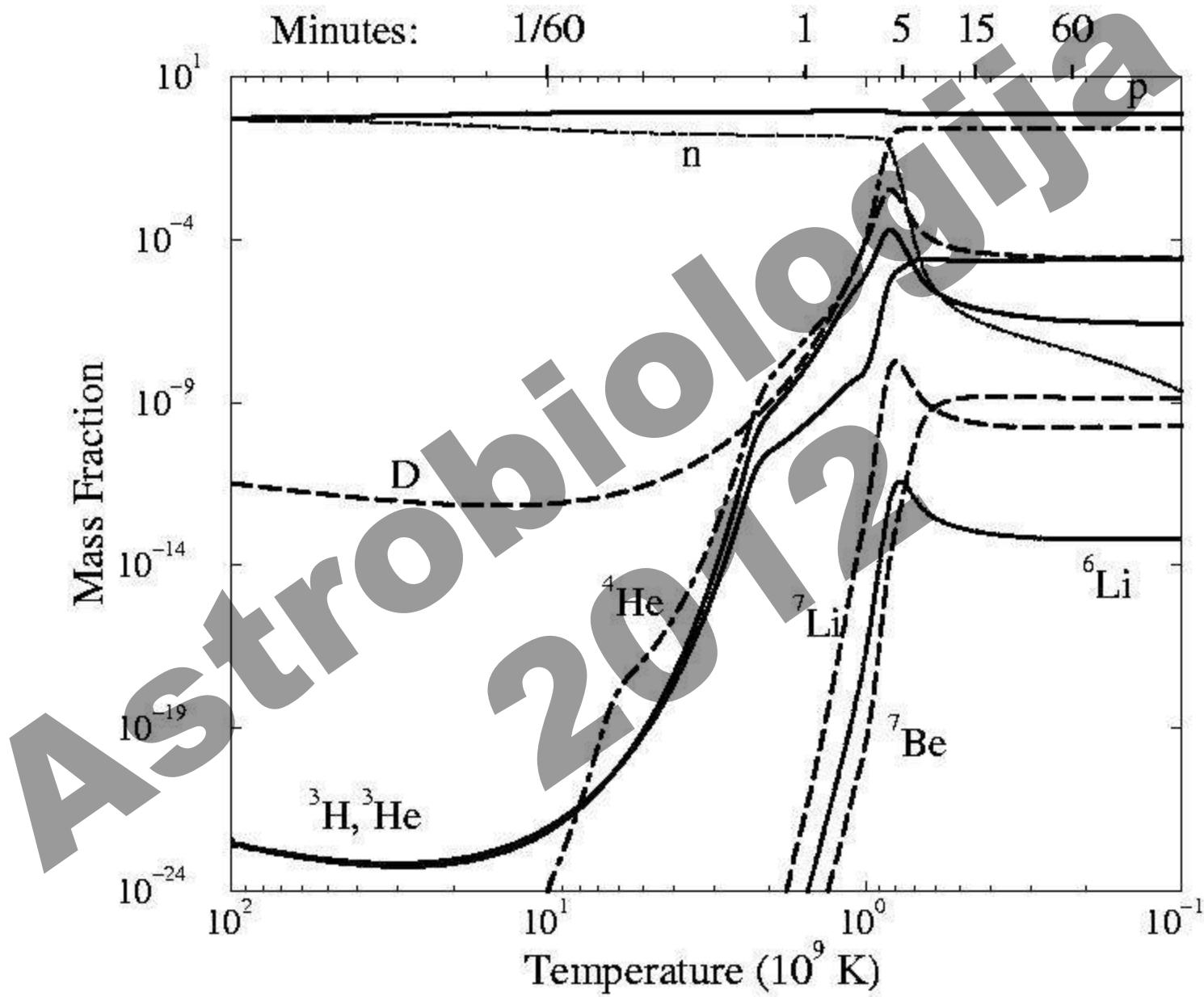
- Prvi detaljni proračuni
Wagoner, Fowler and Hoyle
- Osnovni principi
 - Na veoma visokim T , neutroni i protoni su u ravnoteži:
 $p + e^- \leftrightarrow n + \nu$
 - Odnos neutron:proton dat je sa $\exp(-\Delta m c^2 / kT)$ gde je Δm razlika u masi, a T temperatura na kojoj se neutrini „zamrzavaju“ (freeze-out, $\sim 10^{10}$ K)
 - To je u praksi $\sim 1:5$



DEUTERIJUMSKO „USKO GRLO“

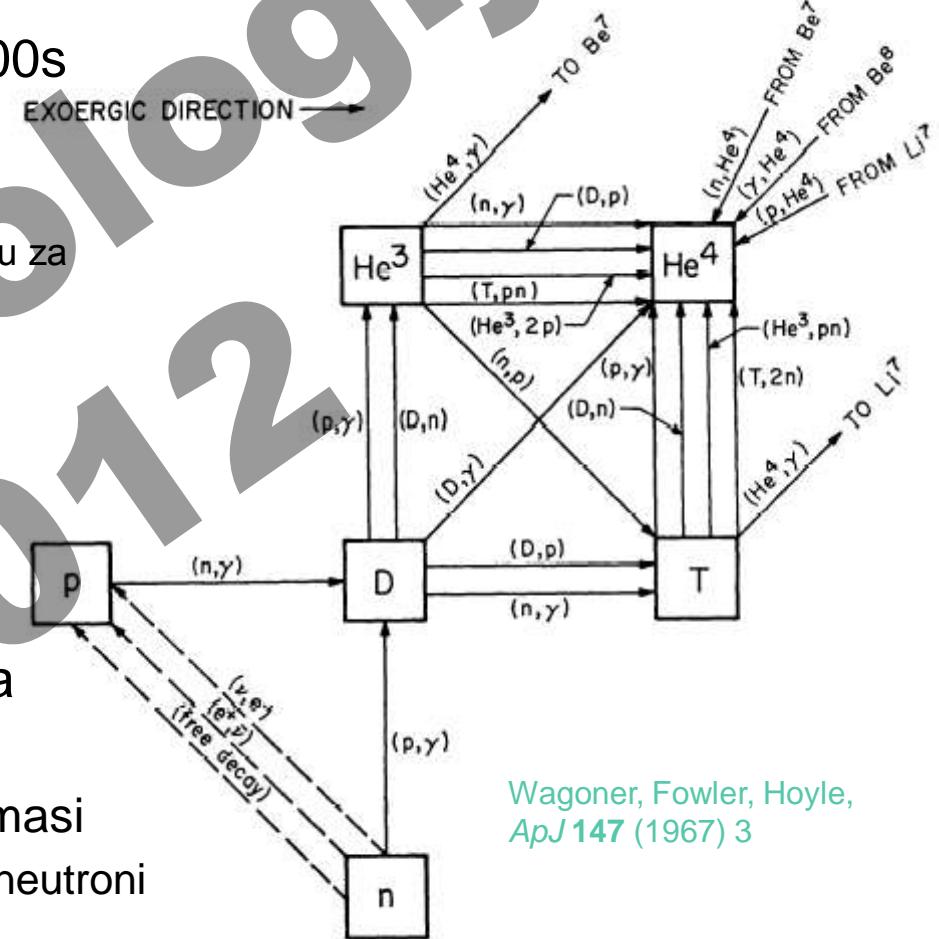
- Kada jednom nastanu veće količine deuterijuma, teža jezgra nastaju veoma brzo
- Post-deuterijumske reakcije se odvijaju kroz jake kanale, sa velikim presecima i visokim stopama reakcije
- Reakcije koje vode do helijuma su brze





DEUTERIJUM: KLJUČ SVEGA

- Kako se univerzum hlađi, na $t = 200s$
 - $p + n \leftrightarrow d + \gamma$
 - Deuteroni se grade ispod $T \sim 10^9 K$
 - Pozadinski fotonii više nemaju energiju za povratnu reakciju
 - $d + p \rightarrow {}^3He + \gamma$
 $d + n \rightarrow {}^3H + \gamma$
 $d + d \rightarrow {}^3H + p$ or ${}^3He + n$
 - Brze reakcije tada vode do 4He (i pomalo 7Li)
 - Ultimativno svaki neutron završava kao 4He !
 - 4He frakcija $\sim 1:8$ po broju, $1:2$ po masi
 - Zapravo malo manje pošto se neki neutroni raspadaju!



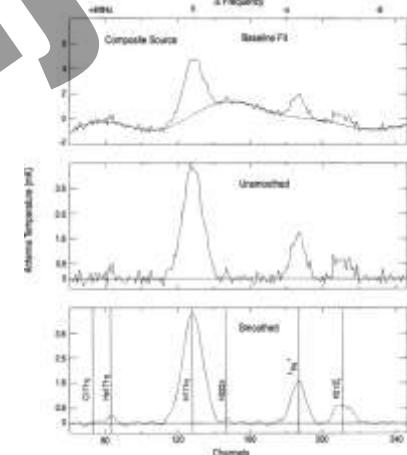
Wagoner, Fowler, Hoyle,
ApJ 147 (1967) 3

ŠTA DOBIJAMO?

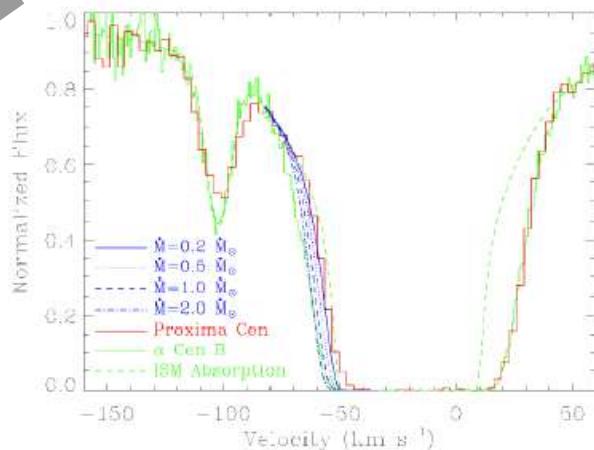
- Konačne količine ^2H , ^3He , ^4He i ^7Li zavise od
 - neutronskog vremena života (mereno u laboratoriji)
 - 885.7 ± 0.8 s (PDG, 2004)
 - broja vrsta neutrina (isto kao i CMB)
 - pošto u because eri dominacije zračenja $H^2 \propto \rho_{\text{rel}} = \rho_\gamma + N_\nu \rho_\nu$
 - 2.984 ± 0.008 (kombinovani LEP eksperimenti)
 - H (mereno astronomski: HST, WMAP)
 - 72 ± 8 km/s/Mpc (HST), 70.1 ± 1.3 km/s/Mpc (WMAP)
 - Gustine bariona (tj. koncentracije protona+neutrona)

POSMATRANJA LAKIH ELEMENATA

- Helijum 4
 - spektri zvezda Pop. II
 - veliki faktor korekcije za zvezdanu nukleosintezu
- Helijum 3
 - Meren u radio domenu (spinska linija $^3\text{He}^+$ at 3.46 cm)
- Deuterijum
 - linije se mogu razdvojiti od ^1H
 - „astracija“ ga potpuno uništava
 - trenutno najbolje izmereni izotop
- Litijum 7
 - meren u spektrima hladnih zvezda
 - proizvode ga i kosmički zraci („spalacija“), a uništavaju zvezde
 - rezultati nisu baš saglasni („litijumska anomalija“)



Bania et al., *ApJSS*
113 (1997) 353



Linsky, Sp. Sci. Rev. 106 (2003) 49

VISOKOPRECIZNA KOSMOLOGIJA

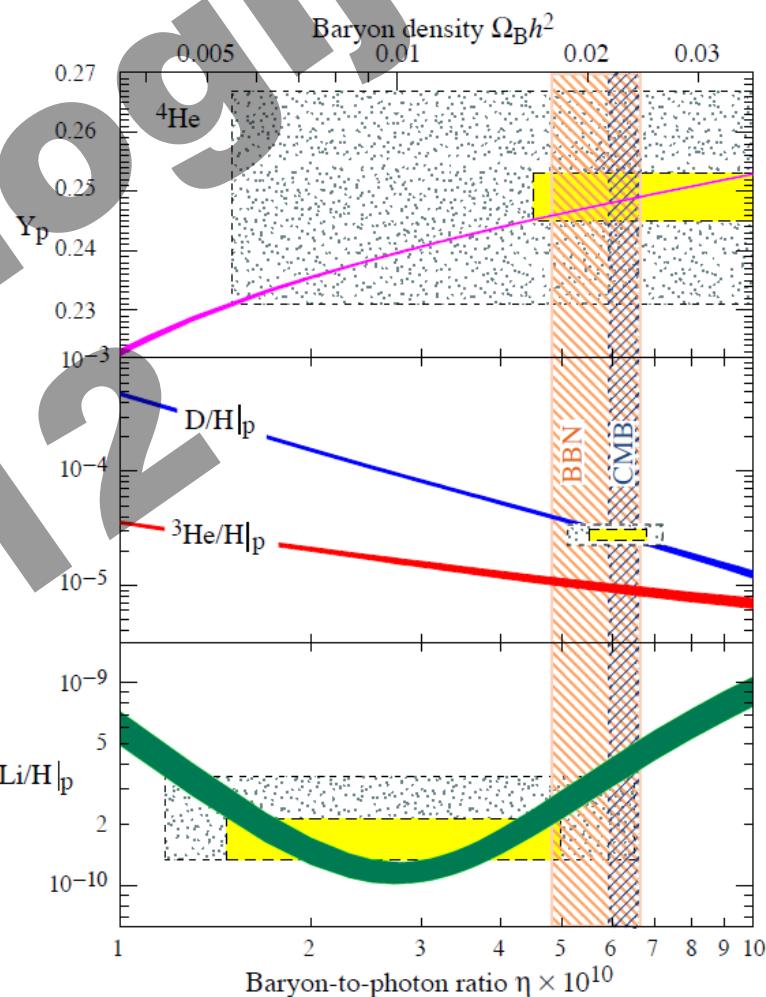
- Trenutni rezultati

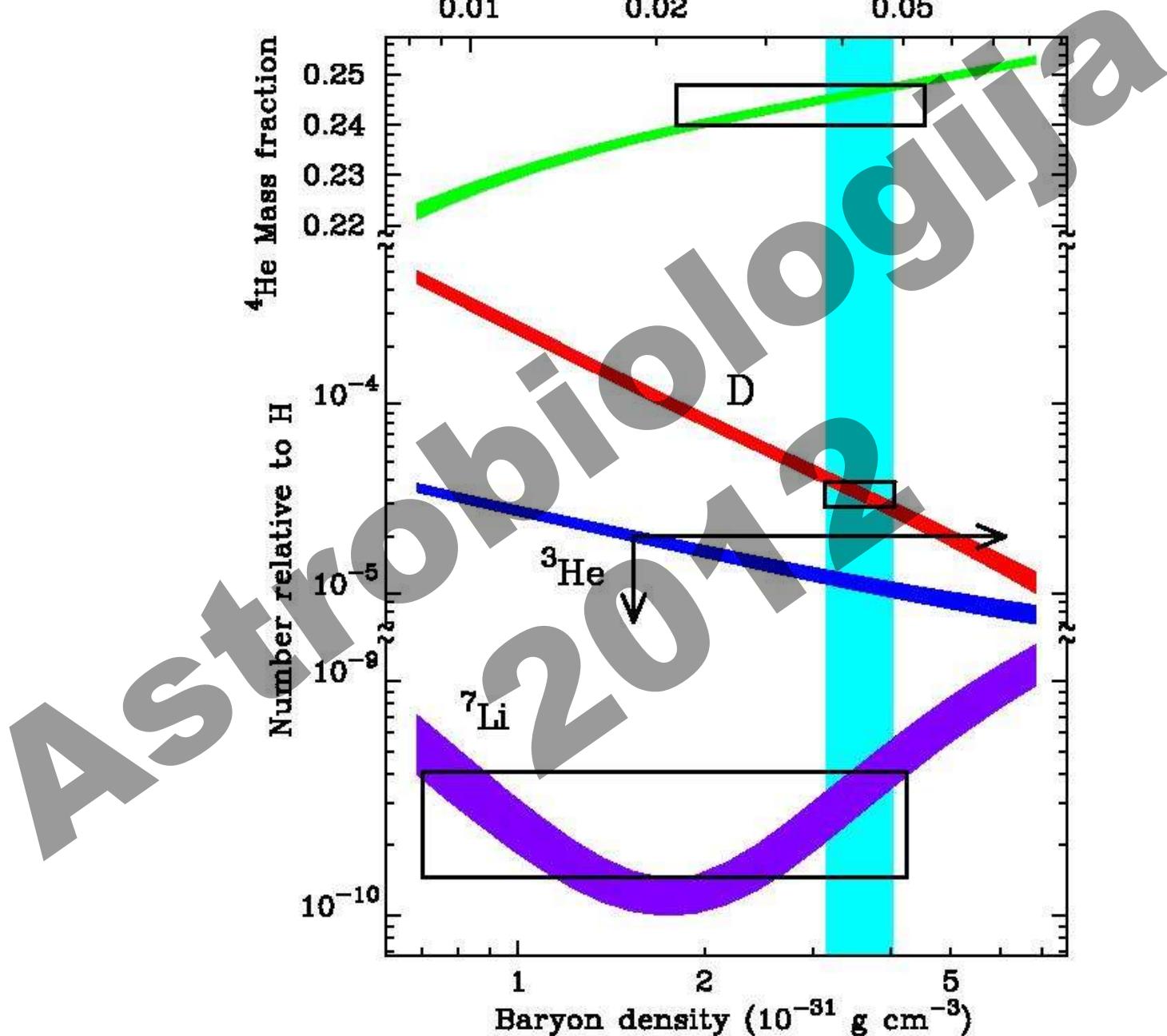
Fields and Sarkar, PDG 2008

- $D/H = (2.84 \pm 0.26) \times 10^{-5}$
- $^7\text{Li}/H = (1.23 \pm 0.06) \times 10^{-10}$
 - Ali moglo bi biti i za faktor 2 više
- $Y = 0.249 \pm 0.009$
- ^3He je izmeren samo u Mlečnom puštu – sistematske greške suviše velike da bi bio koristan

- ^7Li je donekle nesaglasan

- Ali možda je uništen u ranom svemiru u zvezdama Pop III
- D/H je saglasan sa WMAP Ω_b
- $0.018 \leq \Omega_b h^2 \leq 0.022$





Neutrinske generacije i BBN

