TEORIJA VEČNOG STANJA

Velika kosmološka kontroverza
(1948-1965)

05.06.2015.

ZAŠTO VEČNO STANJE?

- Definiše prve empirijske testove – rađanje posmatračke kosmologije
- Istorija ideja pokazuje centralni značaj koncepata (kosmološki princip, početni uslovi, itd.)
- Pojedine ideje ponovo aktuelne u inflatornoj i kvantnoj kosmologiji
- Sjajan pedagoški primer!

IZVORI I PRETEČE

- Predsokratovski ciklizam: Heraklit, Empedokle, atomisti
- Stoicizam
- „Večito vraćanje istog“: ibn Haldun, Niče, Špengler
- Tradicija gradualizma u geonaukama: “Sadašnjost je ključ prošlosti”
- Redukcionizam

I sve što je bilo, ponovo će biti,
I sve što se činilo opet će se činiti;
I nema ništa pod suncem.

Propovednik, 1:9

GRADUALIZAM U PROSVETITELJSTVU

- *If the succession of worlds is established in the system of nature, it is in vain to look for anything higher in the origin of the earth. The result, therefore, of our present enquiry is* ***that we find no vestige of a beginning—no prospect of an end****.*

James Hutton (1788)

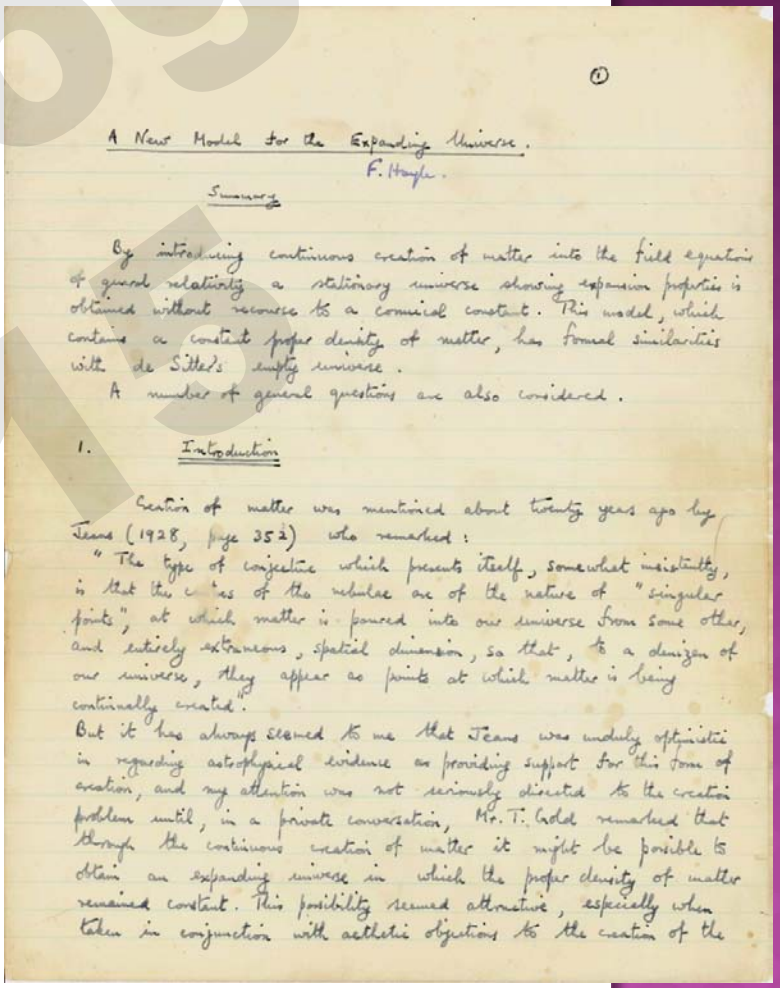
RAZLOZI ZA NEZADOVOLJSTVO...

- Problem starosti svemira
- Problem singularnog početka $t = 0$
- Problem nastanka strukture
- Problem strele vremena
- Problem porekla hemijskih elemenata (αβγ teorija)
- Problem nesaznatljivih početnih uslova: „Svet je onakav kakav jeste zato što je bio onakav kakav je bio.“ (ser Fred Hojl)

KEMBRIDŽ, 1948...

DVA OBLIKA JEDNE TEORIJE...

- Bondi, H. & Gold, T.: „The Steady-State Theory of the Expanding Universe“ *MNRAS* **108**, 252
- Hoyle, F.: „A New Model for the Expanding Universe“ *MNRAS* **108**, 372
- Razni urbani „mitovi o nastanku“...



(1)

A New Model for the Expanding Universe.

F. Hoyle.

Summary.

By introducing continuous creation of matter into the field equations of general relativity a stationary universe showing expansion properties is obtained without recourse to a cosmical constant. This model, which contains a constant proper density of matter, has formal similarities with de Sitter's empty universe.

A number of general questions are also considered.

1. Introduction.

Creation of matter was mentioned about twenty years ago by Jeans (1928, page 352) who remarked:

"The type of conjecture which presents itself, somewhat insistently, is that the centres of the nebulae are of the nature of "singular points", at which matter is poured into our universe from some other, and entirely extraneous, spatial dimension, so that, to a denizen of our universe, they appear as points at which matter is being continually created."

But it has always seemed to me that Jeans was unduly optimistic in regarding astrophysical evidence as providing support for this form of creation, and my attention was not seriously directed to the creation problem until, in a private conversation, Mr. T. Gold remarked that through the continuous creation of matter it might be possible to obtain an expanding universe in which the proper density of matter remained constant. This possibility seemed attractive, especially when taken in conjunction with aesthetic objections to the creation of the

THE STEADY-STATE THEORY OF THE EXPANDING UNIVERSE

H. Bondi and T. Gold

(Received 1948 July 14)

Summary

The applicability of the laws of terrestrial physics to cosmology is examined critically. It is found that terrestrial physics can be used unambiguously only in a stationary homogeneous universe. Therefore a strict logical basis for cosmology exists only in such a universe. The implications of assuming these properties are investigated.

Considerations of local thermodynamics show as clearly as astronomical observations that the universe must be expanding. Hence, there must be continuous creation of matter in space at a rate which is, however, far too low for direct observation. The observable properties of such an expanding stationary homogeneous universe are obtained, and all the observational tests are found to give good agreement.

The physical properties of the creation process are considered in some detail, and the possible formulation of a field theory is critically discussed.

1. *The perfect cosmological principle*

1.1. The unrestricted repeatability of all experiments is the fundamental axiom of physical science. This implies that the outcome of an experiment is not affected by the position and the time at which it is carried out. A system of cosmology must be principally concerned with this fundamental assumption and, in turn, a suitable cosmology is required for its justification. In laboratory physics we have become accustomed to distinguish between conditions which can be varied at will and the inherent laws which are immutable.

Such a distinction between the "accidental" conditions and the "inherent" laws and constants of nature is justifiable so long as we have control over the "accidental", and can test the validity of the distinction by a further experiment. In astronomical observations we do not have this control, and we can hence never prove which is "accidental" and which "inherent". This difficulty, though logically a very real one, need not concern us in an interpretation of the dynamics of the solar system. We may be satisfied when we discover that the solar system with all its numerous orbits is accurately one of the many systems permitted by our "inherent" laws.

But when we wish to consider the behaviour of the entire universe, then the logical basis for a distinction between "inherent" laws and "accidental" conditions disappears. Any observation of the structure of the universe will give as unique a result as, for instance, a determination of the velocity of light or the constant of gravitation. And yet, if we were to contemplate a changing universe we should have to assume some such observations to represent "accidental" conditions and others "inherent" laws.

Such assumptions were in fact implied in all theories of evolution of the universe; they were necessary to specify the problem. Without them, there would be no rules and hence unlimited freedom in any extrapolation into the future or into the past. Some such sets of assumptions may be intellectually much more

A NEW MODEL FOR THE EXPANDING UNIVERSE

F. Hoyle

(Received 1948 August 5)

Summary

By introducing continuous creation of matter into the field equations of general relativity a stationary universe showing expansion properties is obtained without recourse to a cosmical constant.

1. *Introduction.*—Creation of matter was mentioned about twenty years ago by Jeans (**1**) who remarked:

"The type of conjecture which presents itself, somewhat insistently, is that the centres of the nebulae (galaxies) are of the nature of singular points, at which matter is poured into our universe from some other and entirely extraneous spatial dimension, so that, to a denizen of our universe, they appear as points at which matter is being continually created". Subsequent astrophysical developments have, however, shown little support for this particular form of creation.

More recently Dirac (**2**) has pointed out that continuous creation of matter can be related to the wider questions of cosmology. The following work is concerned with this aspect of the matter and arose from a discussion with Mr T. Gold who remarked that through continuous creation of matter it might be possible to obtain an expanding universe in which the proper density of matter remained constant. This possibility seemed attractive, especially when taken in conjunction with aesthetic objections to the creation of the universe in the remote past. For it is against the spirit of scientific enquiry to regard observable effects as arising from "causes unknown to science", and this in principle is what creation-in-the-past implies.

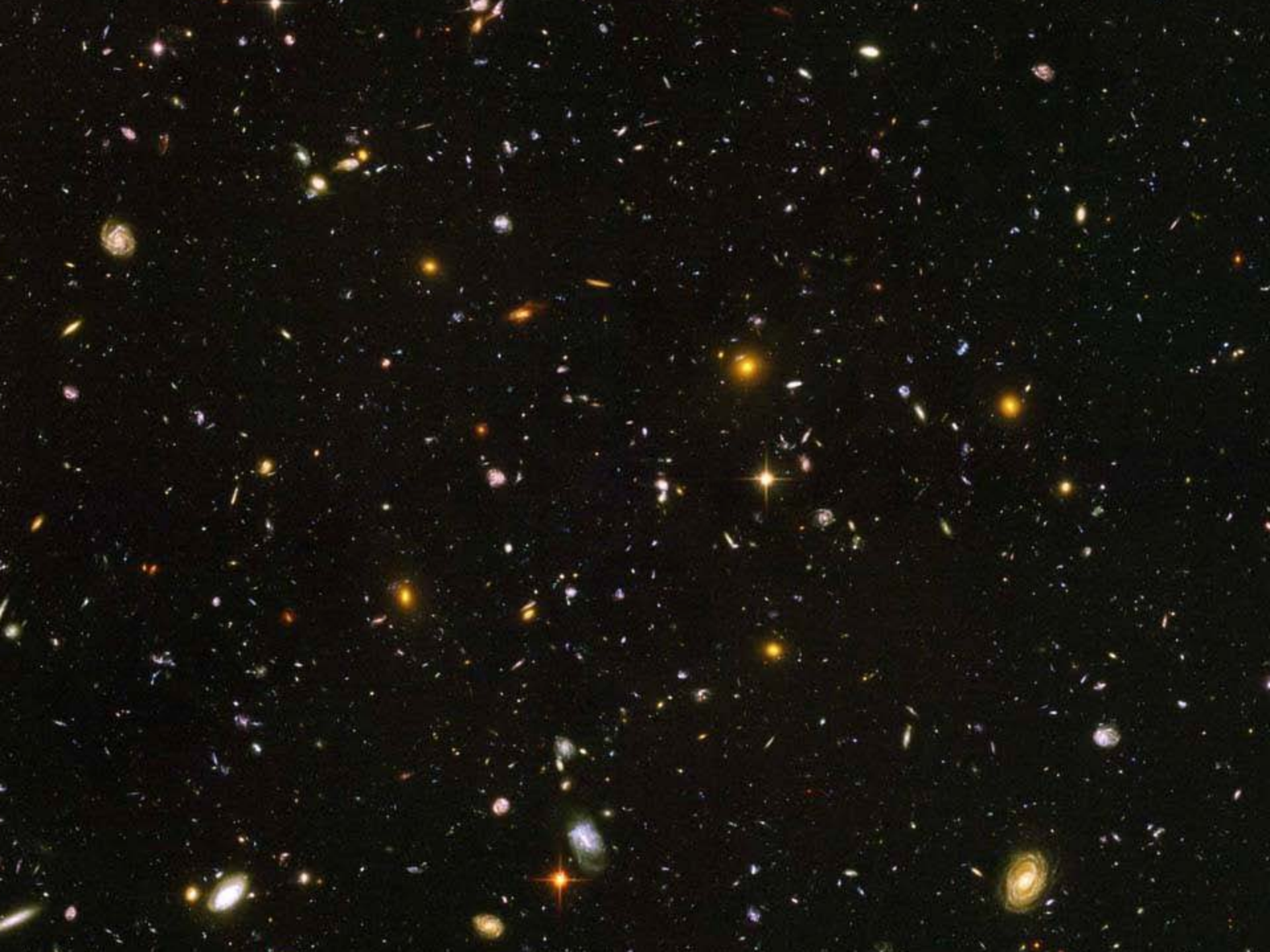
The writer's thanks are due to Mr H. Bondi for valuable comments on the present paper and also for many discussions on the general problems of cosmology.

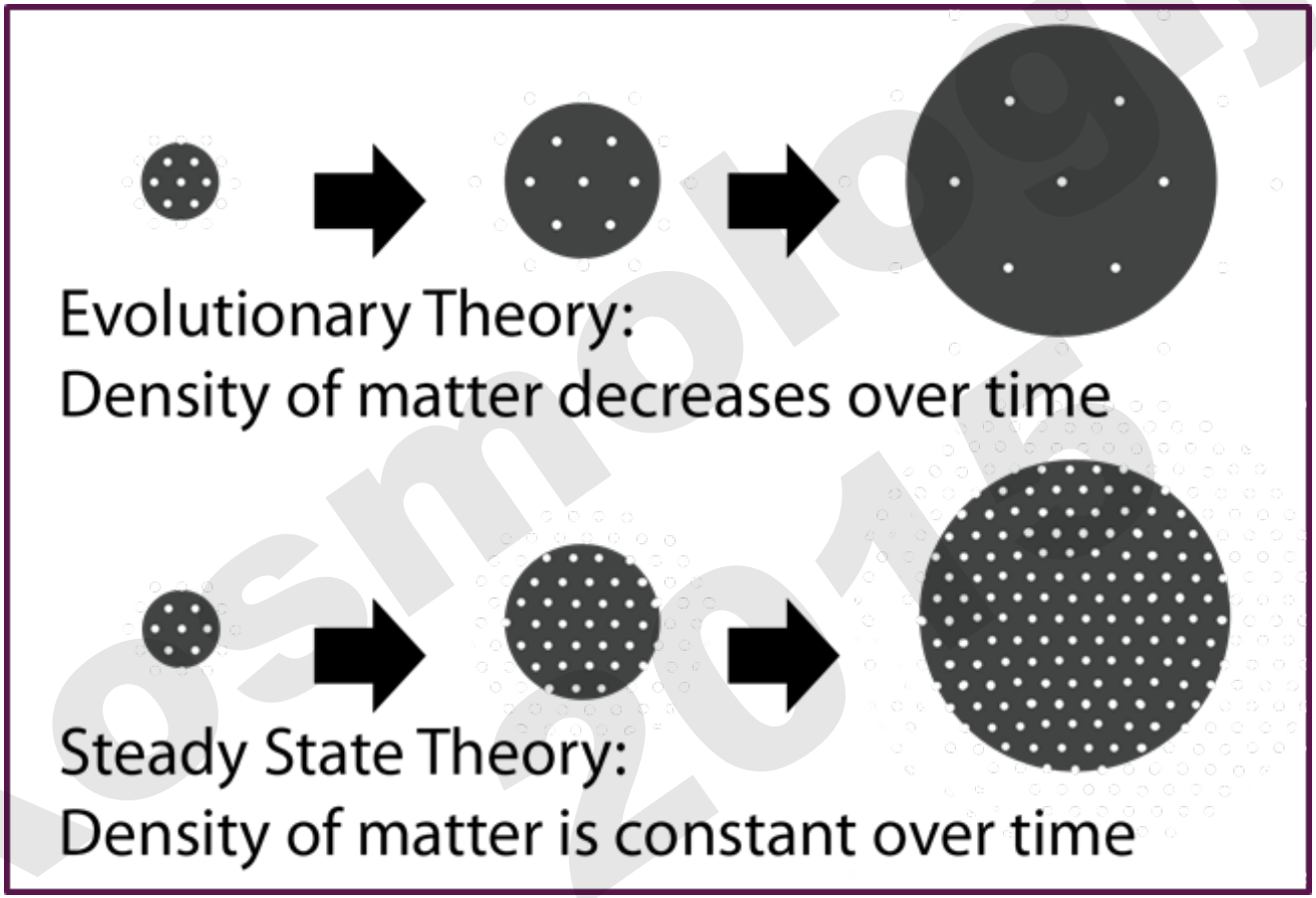
2. *Newtonian Universes.*—We begin by mentioning the difficulties occurring in current theories of the expanding universe. A comprehensive review of cosmology, based on Einstein's general theory of relativity, has been given by Robertson (**3**). Milne and McCrea (**4**) have obtained the remarkable result that Newtonian analogues exist for all the more important models considered by Robertson. Although later we shall go over to the formalism of the relativity theory, it is convenient in these preliminary remarks to use the Newtonian equivalent models.

The work of Milne and McCrea starts from the cosmological principle applied in the narrow sense. According to the narrow cosmological principle, the distribution of material and momentum relative to an observer attached to a particular particle is identical with the distribution relative to an observer attached to any other particle, provided the comparison *refers to the same value of the time.* The latter proviso weakens the equivalence of observers. When the cosmological principle is used in its wide sense this proviso is removed and equivalence would have to be applied even if the two observers carried out their measurements at different times. It is important to notice that the cosmological principle ignores proper motions arising from local condensations of matter. That is,

SAVRŠENI KOSMOLOŠKI PRINCIP

Svemir je (na velikim skalama) homogen u 4D prostorvremenu



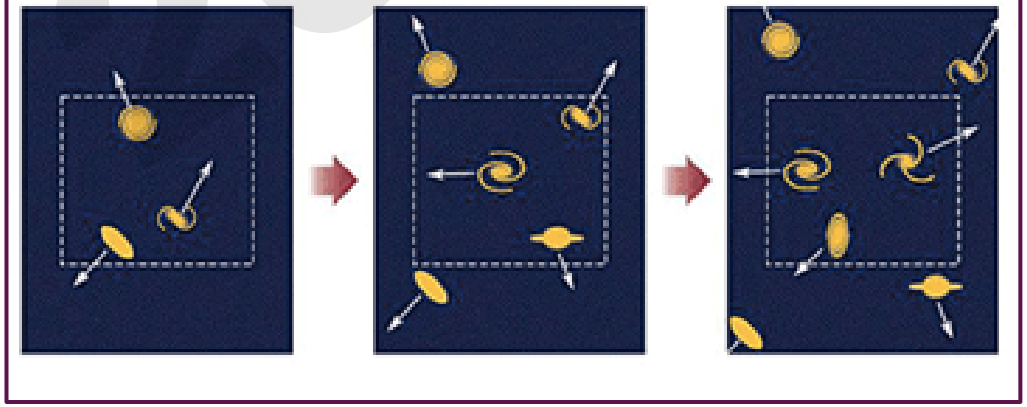


...DA BI SVE OSTALO ISTO

- Metrika mora biti FLRW tipa, ali i faktor skaliranja mora biti samosličan

$$ds^2 = c^2 dt^2 - e^{2Ht}\left[dr^2 + r^2\left(d\theta^2 + \sin^2\theta\, d\varphi^2\right)\right]$$

- Formalno = de Siter
- Gustina (i sve ostalo) ostaje u proseku isto
- Očuvanje mase u koordinatnoj zapremini



ZLOGLASNA POSLEDICA...

- Neprekidno stvaranje nove materije u prostorvremenu!
- Stopa stvaranja:

$$\frac{1}{V}\dot{M} = 3H\rho$$

- Šta je „fundamentalnije“: koordinatna ili usputna zapremina?
- Nije toliko neuobičajeno (Bor, Schrodinger, Dirac, Jordan)
- John North (1965): „The principle of energy conservation has survived, of course, because energy is defined as that which is conserved.“

HOJLOVA VERZIJA TEORIJE POLJA

- Modifikacija Ajnštajnovih jednačina sa C-tenzorom:

$$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = -\kappa \left(T_{\mu\nu} + C_{\mu\nu} \right)$$

$$C_{\mu\nu} = \phi_{;\mu\nu} \qquad g^{\mu\nu} \phi_{;\mu\nu} = K\rho \qquad T^{\mu\nu}_{;\nu} = -C^{\mu\nu}_{;\nu}$$

- U docnijoj varijanti (Hoyle, McCrea 1951): komponenta sa **negativnim pritiskom** (preteča tamne energije)
- Decenijama kasnije: „legitimizacija“ (Kazimirov efekat, Hokingovo zračenje, inflacija, etc.)

LICEM U LICE...

- Singularni početak
- Očuvanje energije, barionskog broja
- Mnoštvo modela
- Kosmološki princip
- Problem starosti objekata
- Čestični horizont i (?) horizont događaja
- q_0 = ??? (većina modela > 0)
- Konačna starost izvora rešava Olbersov par.

Veliki prasak

- Nema početka
- Narušenje očuvanja energije, bar. broja
- Jedinstveni model
- Savršeni kosmološki princip
- Nema problema starosti
- Samo horizont događaja
- q_0 = -1
- Crveni pomak rešava Olbersov paradoks

Večno stanje

STAROST GALAKSIJA?

- Funkcija raspodele galaksija **po vremenu:**

$$f(t) = \exp(3Ht)$$

- Koncentracija galaksija starosti u (τ,τ+dτ):

$$n\,df(\tau) = 3nH\exp(-3H\tau)\,d\tau$$

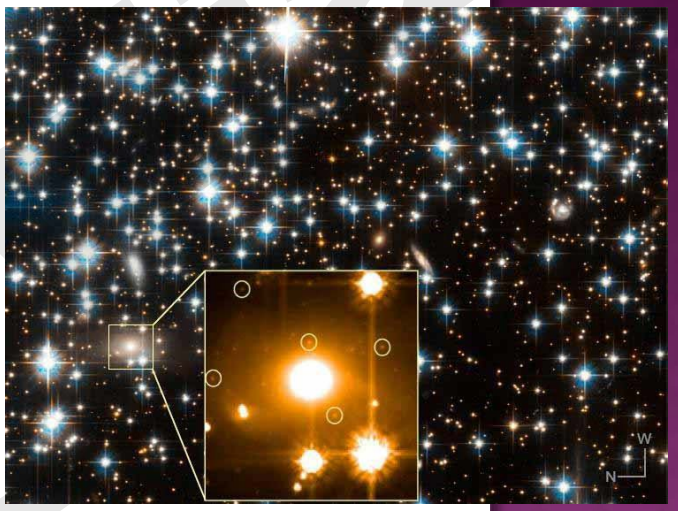
- Postoje galaksije **proizvoljno velike starosti**
- Zanimljivi (metafizički) problemi: postoje li galaksije proizvoljno velike mase? postoje li **naseljena** mesta proizvoljno velike starosti?

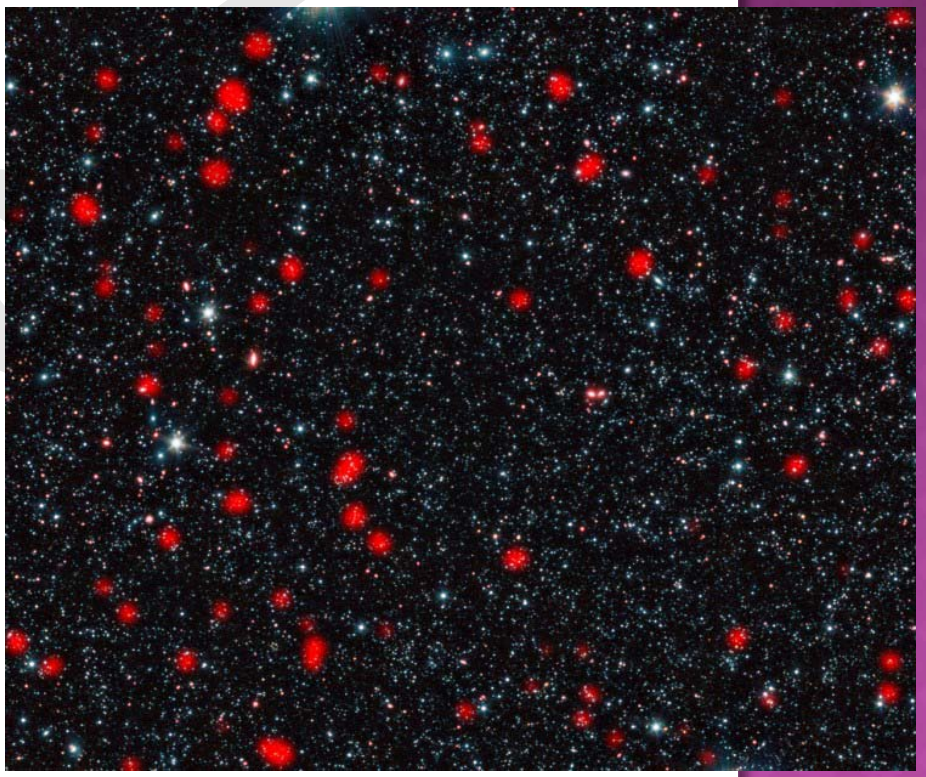
FALSIFIKACIJA?

- Falsifikacionizam: teorija je naučna samo ako se može opovrgnuti (Popper)
- Bondi: Večno stanje se lako može opovrgnuti!
- Objekti koji su postojali samo u određenim epohama istorije svemira?
- Bilo šta što se desilo samo **jedanput**?
- Bilo kakav nepovratan proces?

LAŽNA UZBUNA: STEBBINS-WHITFORDOV EFEKAT

- Kakvih su boja udaljene eliptične galaksije?
- J. Stebbins & A. Whitford (1948): crvenije nego obližnje
- Bondi, Gold & Sciama (1954): posmatranja su nepouzdana
- Stebbins 1956. i zvanično povlači originalni rezultat
- Ironija: današnji rezultati pokazuju **plavlje** boje mladih eliptičkih galaksija...
- Ironija #2: ...ali nešto **manje plave** od očekivanog! (Kalirai et al. 2008)





(NEO)KLASIČNI KOSMOLOŠKI TESTOVI

- Brojanje izvora
- Relacija crveni pomak-magnituda
- Relacija crveni pomak-ugaona veličina
- Prostorna raspodela kvazara
- Starost svemira
- Svi su formulisani i ozbiljno diskutovani tokom perioda 1948-65!

POČETAK RADIO ASTRONOMIJE

- Ser Martin Rajl, Šojer, Hjuiš, Mils
- Sukob sa Goldom oko prirode radio-izvora
- Brojanje radio-izvora kao kosmološki test
- 1C, 2C, 3C,…
- Indeks -3 u Kembridžu, -1.7 u Australiji (!?)
- Hojl: ser Martin bolje da se bavi kriketom…
- Schmidt (1972): brojanje izvora **jeste** nesaglasno sa Večnim stanjem (mada i sa EdS Velikim praskom!)

MILLS CROSS (CSIRO)

RYLE vs. HOYLE

"Your years of toil,"
Said Ryle to Hoyle,
"Are wasted years, believe me.
The steady state
Is out of date.
Unless my eyes deceive me,

My telescope
Has dashed your hope;
Your tenets are refuted.
Let me be terse:
Our universe
Grows daily more diluted!"

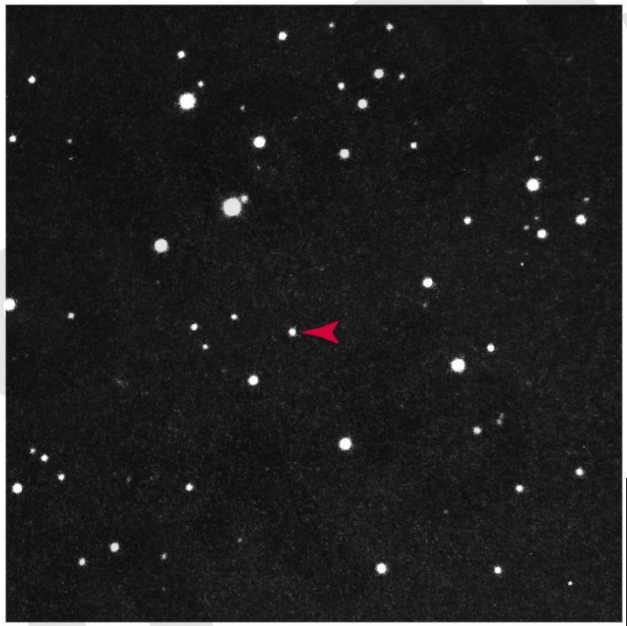
Said Hoyle, "You quote
Lemaître, I note,
And Gamow. Well, forget them!
That errant gang
And their Big Bang—
Why aid them and abet them?

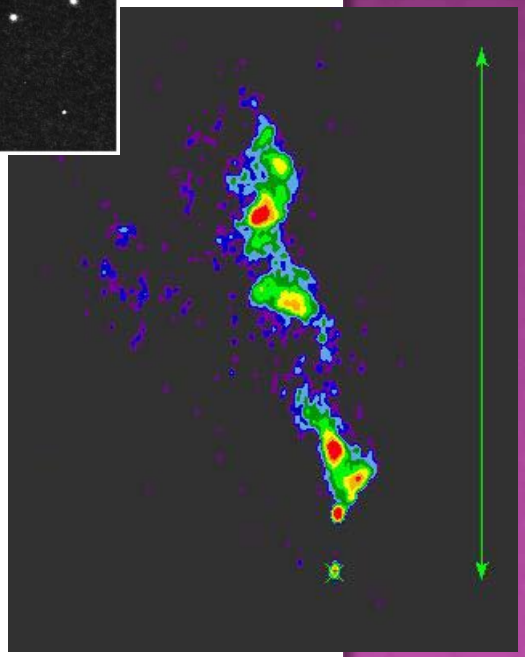
You see, my friend,
It has no end
And there was no beginning,
As Bondi, Gold,
And I will hold
Until our hair is thinning!“

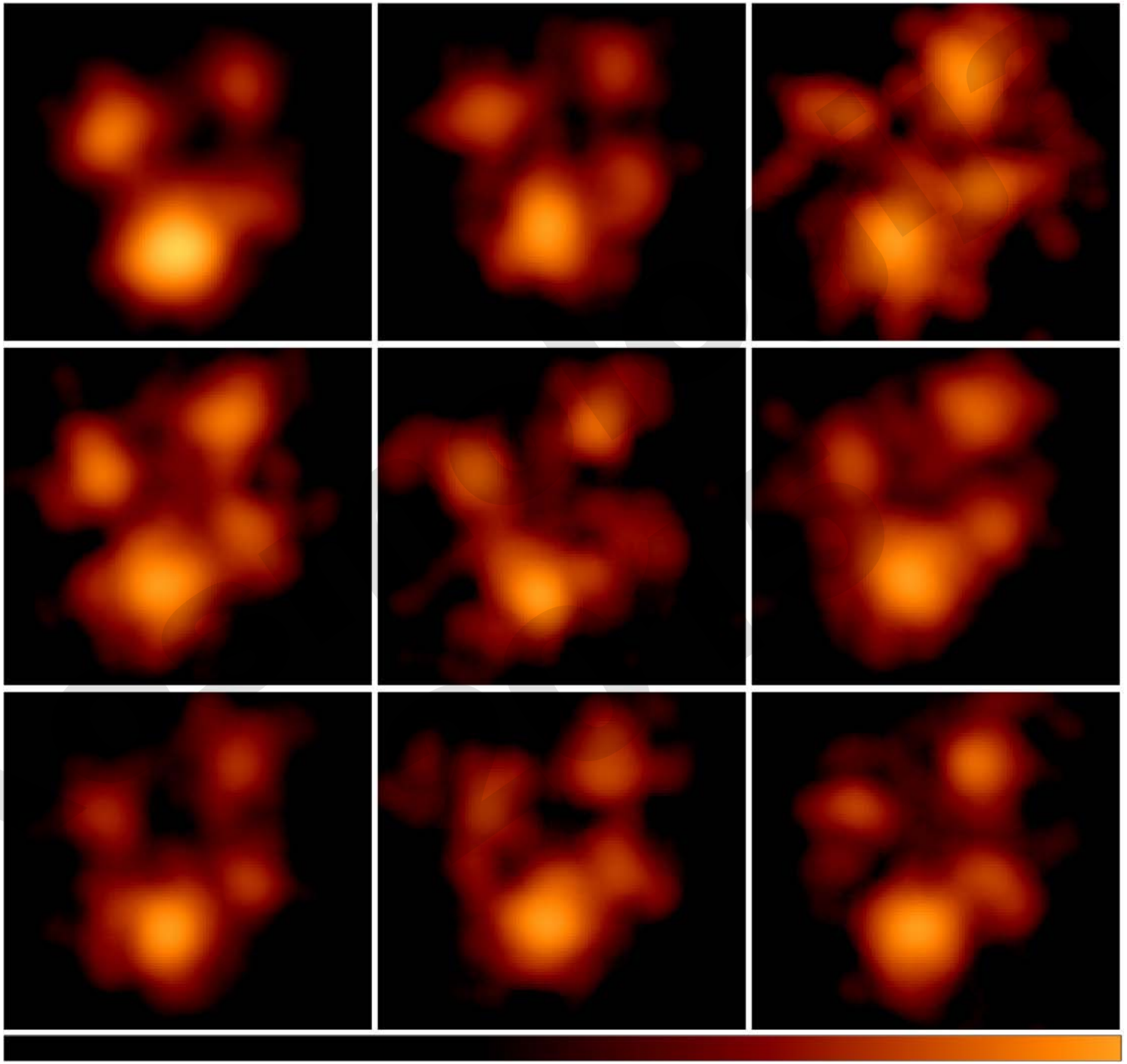
Barbara Gamow (cca. 1960)

PRVI UDARAC: OTKRIĆE KVAZARA

- Misterija 3C48, 3C273…
- Okultacija 1962.
- Marten Schmidt 1963
- Prostorna raspodela kvazara JAKO neuniformna!
- z ~ 2

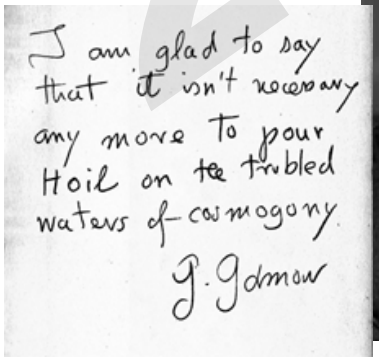


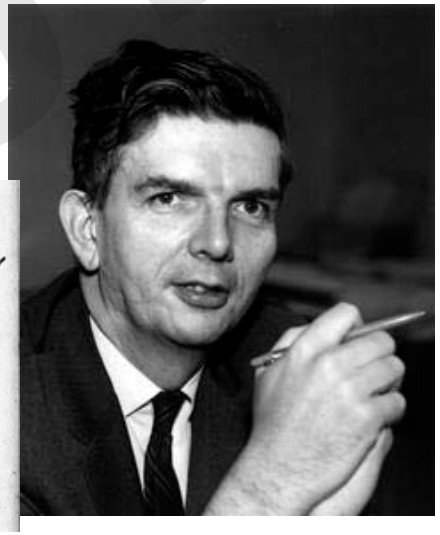


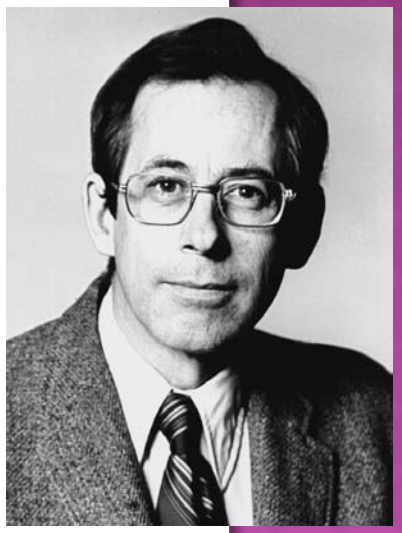


FAJRONT...

- Otkriće CMB-a 1965.
- Diki, Pibls: 3K zračenje nastalo u **jedinstvenoj** epohi rekombinacije!
- Ironija: Hojl prvi skrenuo pažnju na posmatranja MekKelara i 2.3K ekscitaciju
- Nakon 1965. praktično svi zagovornici napuštaju Večno stanje (sem Hojla, Barbidža i Narlikara)
- Primer razrešenja kontroverze u nauci!







αβγ TEORIJA

- Alferova doktorska dizertacija
- Gamovljeva šala sa Beteom
- Zahvat neutrona 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. ALPHER*
Applied Physics Laboratory, The Johns Hopkins University, Silver Spring, Maryland
AND
H. BETHE
Cornell University, Ithaca, New York
AND
G. GAMOW
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 an 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,[1] 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:

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

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,[2] 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 abundances[3] it is necessary to assume the integral of $\rho_n dt$ during the building-up period is equal to 5×10^4 g sec./cm³.

On the other hand, according to the relativistic theory of the expanding universe[4] the density dependence on time is given by $\rho\leqq10^6/t^2$. 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:

$$\int_{t_0}^{\infty}(10^6/t^2)dt\leqq5\times10^4, \qquad (2)$$

which gives us $t_0\leqq20$ sec. and $\rho_0\leqq2.5\times10^5$ g sec./cm³. 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 2.5×10^5 g sec./cm³ which can possibly be understood if we

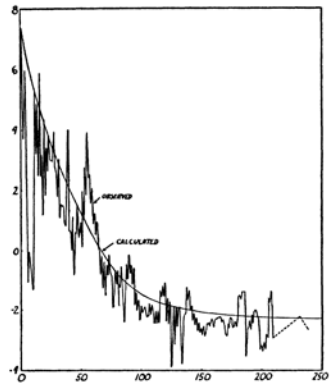
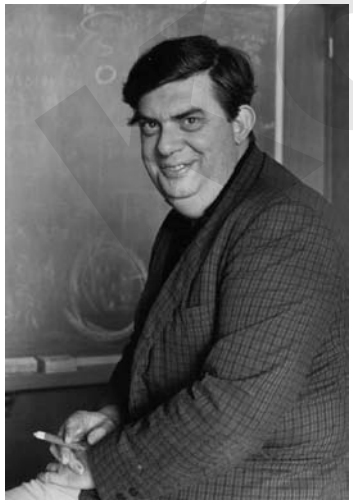
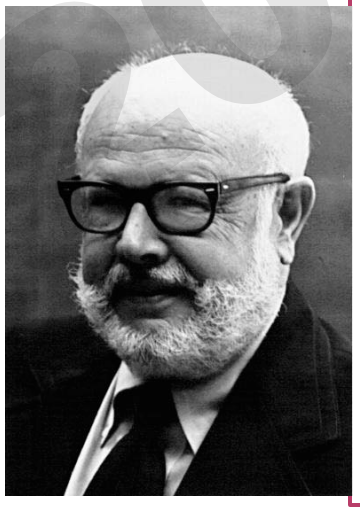


FIG. 1.
Log of relative abundance
Atomic weight

HOJLOV ODGOVOR: ZVEZDANA NUKLEOSINTEZA!

- B^2FH članak
- Jezgra hemijskih elemenata nastaju u unutrašnjostima zvezda **termonuklearnom fuzijom**
- Ova teorija bila je direktno inspirisana kosmološkom kontroverzom!





REVIEWS OF
MODERN PHYSICS

VOLUME 29, NUMBER 4 OCTOBER, 1957

Synthesis of the Elements in Stars*

E. MARGARET BURBIDGE, G. R. BURBIDGE, WILLIAM A. FOWLER, AND F. HOYLE

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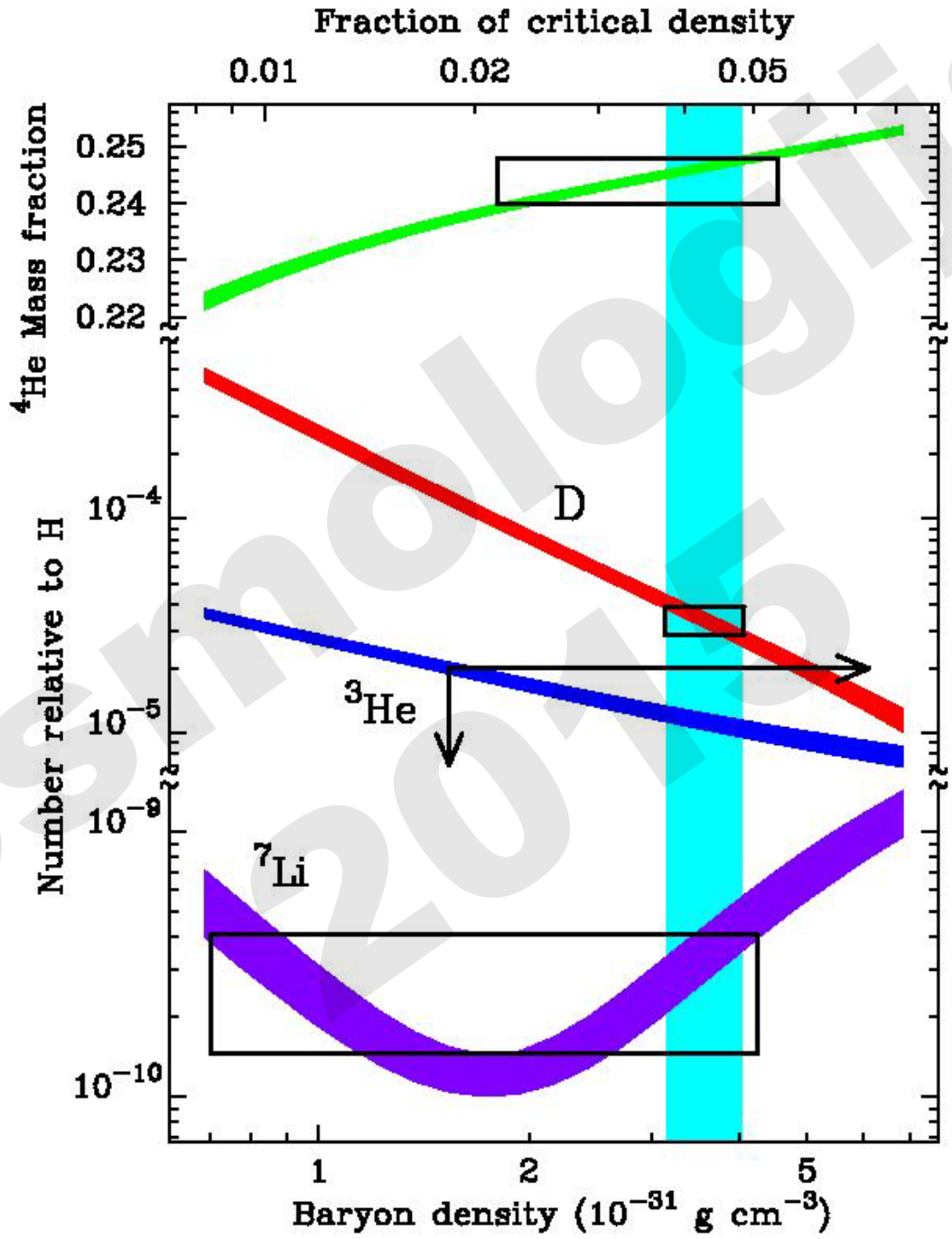
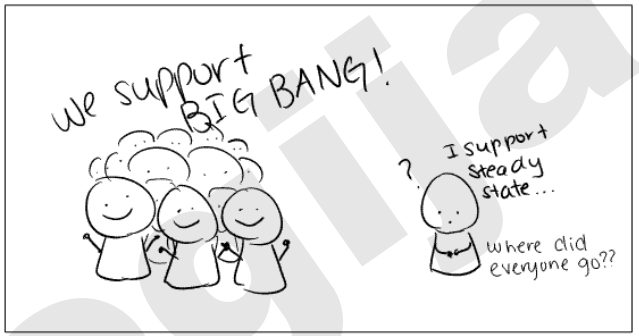
* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.



UMESTO ZAKLJUČKA...



- Večno stanje je odigralo ključnu ulogu u istoriji kosmologije
- Tek sa „Velikom kontroverzom“ kosmologija postaje uistinu opis prirode
- Stacionarnost je i dalje snažna inspiracija: haotična („večna“) inflacija
- Pogrešne teorije mogu biti (bar) podjednako korisne...